HANDBOOK of HEALTH PHYSICS

TENNESSEE VALLEY AUTHORITY

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Tennessee Valley Authority

Revised April 1980

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Section I

INTRODUCTION

This manual has been prepared by the Radiological Hygiene Branch of TVA in an effort to provide the employees of the nuclear plants with the information about radiation needed during daily work. Sections on the types of radiation encountered and the hazards of each are provided. The working guidelines and limits for exposure to radiation are given as are the methods for control of radiation. The various instruments used for measuring radiation are included. Procedures detailing exactly what a person should do if he becomes contaminated with radioactive materials and decontamination procedures are given. A glossary of radiation terms is included for each employee's reference.

The various sections of the manual provide basic information as to limits and procedures, however, particular attention should be given to that portion of the sections listing "Requirements." In addition, the section on "Safe Practices" is important for general rules of conduct as to what to do and not do in radiation work.

New printings of this manual will be made as needed with the necessary revisions to keep the information as accurate as possible. No attempt will be made to provide revisions to manuals already issued.

Plant health physics and plant management will receive current copies with the most recent revisions. Copies of the revisions will be placed on plant bulletin boards for employees to read.

SECTION IA

TVA Policy for Keeping Occupational Radiation Exposures and Releases of Radioactive Materials to Unrestricted Areas as-Low-as-Reasonably-Achievable (ALARA)

A. ALARA Policy

In all operations with radioactive materials at the nuclear plant, every reasonable effort shall be made to maintain radiation exposures to employees and the general public and the release of radioactive material to unrestricted areas as-low-as-reasonably-achievable (ALARA) below the limits specified in 10 CFR 20 (Standards for Radiation Protection). Reasonably achievable is determined by the state of technology and the economics of improvements in relationship to the benefits to the public health and safety and other societal and socioeconomic considerations, and in relation to the utilization of atomic energy in the public interest. TVA is committed to the ALARA guidance set forth in Nuclear Regulatory Commission (NRC) Regulatory Guides 8.8 and 8.10 in the design and operation of all of its nuclear plants. (See TVA Instruction VIII, Radiological Hygiene, the Division of Power Production's <u>Division Procedure Manual</u>, DPM No. N74A19 and <u>Generating Plant Design Philosophy Improvement Manual</u>, DPIR No. NG-4.)

1. Discussion

To accomplish the above policy requires the following major considerations: (1) management commitment and support; (2) careful design of facilities and equipment; (3) good radiation protection practices, including good planning and the proper use of appropriate equipment by qualified, well-trained personnel; and (4) continual vigilance by the health physics staff to reduce exposure, minimize releases, and control contamination. This section deals with defining organizational responsibility in the administration and implementation of the ALARA policy at the nuclear plant.

2. Responsibilities

a. Radiological Hygiene Branch (RHB)

The Radiological Hygiene Branch, Division of Occupational Health and Safety, is responsible for radiological hygiene activities at the plant, for radiological surveillance of the plant environment, and for developing and maintaining a comprehensive Radiological Emergency Plan (REP). A central staff provides the administrative, technical, instrumentation, dosimetric, and analytical laboratory support services to carry out these functions. Administrative support in behalf of the operation of the inplant health physics program consists of:

(1) Developing and applying radiation standards and procedures;

(2) Reviewing and complying with new regulations as they are promulgated by the NRC;

(3) Maintaining cognizance of NRC regulatory guides, national consensus radiation protection standards, and new technology and recommending appropriate implementation at the plant where applicable to current operations;

(4) Participating in development of plant documents and in the generation of reports required by regulatory agencies;

(5) Conducting and participating in design effectiveness studies to improve the radiation protection features of future plants;

(6) Providing specialized training in ALARA; and

(7) Coordinating formal audits of plans, procedures, and activities carried out at the plant to appraise the effectiveness of the ALARA program.

b. Plant Health Physics Unit

The plant health physicist and his staff are charged with the responsibility of taking the lead in the implementation of a program to maintain occupational radiation exposures ALARA under the functional direction of the plant superintendent. The plant health physicist is responsible for the direction of an effective program of radiation protection for all inplant operations involving potential radiation hazards.

To accomplish the ALARA objective the health physics unit shall conduct surveillance programs and investigations to assure that occupational exposures are as far below the regulatory limits as reasonably achievable. They shall be vigilant in searching out new and better ways to perform all radiation jobs with less exposures. There are several aspects to this responsibility.

(1) The health physics unit shall be aware of the origins of radiation exposures in the plant--by location, operation, and job category. The health physics unit shall also be aware of the trends in exposures.

(2) The health physics unit shall look for ways to reduce exposures by participating in planning operations and procedural development, by reviewing operating procedures that may affect radiati

safety, and by maintaining surveillance of plant operations to identify situations in which exposures can be reduced. Indicated changes shall be promptly brought to the attention of the plant operations staff and implemented, if practicable. In concert with the plant superintendent, procedures for receiving and evaluating employee suggestions relating to radiation protection shall be developed. Employees shall be made aware of these procedures for receiving suggestions.

(3) When unusual exposures occur, the health physics unit shall direct and participate in an investigation of the circumstances of such exposures and take steps to reduce the likelihood of similar future occurrences. For each such occurrence, the health physicist shall be able to demonstrate that such an investigation has been carried out, that conclusions were reached as a result of the investigation, and that corrective action was taken, as appropriate.

(4) The health physics unit shall be responsible for ensuring that (a) proper radiation protection equipment and supplies are specified and (b) that radiation survey instruments and respiratory protective equipment are maintained in good working order and are used properly.

c. <u>Division of Power Production</u>

DPP's procedure for the implementation of ALARA in the operation of its nuclear plants is given by DPM Nos. N74A19, N74A19a, N74A19b, and N74A19c, and the plant standard practice procedure which is available to all nuclear plant employees.

d. <u>Individual Employee</u>

Individual responsibility for radiation safety is defined in Section 6 of DPM No. N74A19 and the plant standard practice procedure. Employee suggestions for reducing exposure by quicker and better ways of doing tasks are welcomed and procedures for receiving and evaluating employee suggestions in this regard have been established.

Section II

DEFINITIONS

Absorption--The process by which radiation imparts some or all of its energy to any material through which it passes.

Alpha Particle--A positively charged particle emitted from a nucleus and composed of two protons and two neutrons.

amu (Atomic Mass Unit)--One sixteenth of the mass of one neutral atom of oxygen 16; equivalent to 1.66×10^{-24} gm.

Atomic Number (Z)--The number of protons in the nucleus of an atom. The number of orbital electrons of a neutral atom.

Atomic Weight (A)--The mass of a neutral atom of a nuclide usually expressed in terms of atomic mass units (amu) and for practical purposes is equal to the number of protons and neutrons in the nucleus.

Beta Particle--A charged particle emitted from a nucleus and having a mass and charge equal to those of an electron.

Controlled Access Area--All areas where access is controlled due to actual or potential radiological hazards. These include Regulated Areas, Radiation Areas, High Radiation Areas, Airborne Radioactivity Areas, etc.

Curie (Ci)--That quantity of radioactive nuclide disintegrating at the rate of 3.7×10^{10} atoms per second.

Decay--"Disintegration" of the nucleus of an unstable atom by the emission of radiation.

Dyne--The unit of force which, when acting upon a mass of one gram, will produce an acceleration of one centimeter per sec^2.

Electron--Negatively charged particle which is a constituent of every neutral atom. Unit of negative electricity equal to 1.6×10^{-19} coulombs. Its mass is 0.000549 amu.

Energy Units-eV--The amount of energy gained by an electron in passing through a potential difference of one volt. (KeV - 1,000 eV; MeV - 1,000,000 eV)

Erg--Unit of energy which can exert a force of one dyne through a distance of one cm.

Exclusion Area--The area surrounding the reactor, in which the reactor licensee has the authority to determine all activities including exclusion or removal of personnel and property from the area.

Gamma Ray--Short wave length electromagnetic radiation of nuclear origin with a range of wave lengths from 10^{-8} to 10^{-11} cm emitted from the nucleus of an atom.

Half-Life ($T_{1/2}$)--The time required for a radioactive substance to lose one-half of its activity by decay.

Health Physics Representative--The Health Physics Supervisor, the on-shift Health Physics Technician or the Shift Engineer in the absence or unavailability of the preceding persons.

Ion--Atomic particle, atom, or chemical radical bearing an electrical charge, either negative or positive.

Ionization--The process or the result of any process by which a neutral atom or molecule acquires either a positive or a negative charge.

Ion Pair--Two particles of opposite charge usually referring to the electron and positive atomic or molecular residue after the interaction of ionizing radiation with the orbital electrons of atoms.

Isotope--One of several nuclides having the same number of protons in their nuclei and hence belonging to the same element but differing in the number of neutrons and therefore in mass number.

Maximum Permissible Concentration--That concentration of radioactivity in air or water which must not be exceeded without the appropriate dilution or protective equipment.

mR (milliRoentgen)--A submultiple of the Roentgen equal to one 1/1000 of a Roentgen.

Neutron--Nuclear particle with a mass approximately the same as that of a hydrogen atom (1 proton in nucleus) and electrically neutral.

Nucleus--That part of an atom in which the total positive charge and most of the mass are concentrated. Composed of protons and/or neutrons.

Nothing Detectable--Means no activity measured greater than the minimum detectable activity for the appropriate instrument.

Nuclide--A species of atom characterized by the constitution of its nucleus.

Positron--A particle equal in mass to the electron and having an equal but opposite charge.

Proton--A particle of the nucleus having a positive charge numerically equal to the charge of an electron and with a mass of 1 amu.

Quality Factor (QF)--The linear-energy-transfer-dependent factor by which absorbed doses are multiplied to obtain, for purposes of radiation protection, a quantity which expresses on a common scale for all ionizing radiations, the effectiveness of the absorbed dose. This factor was formerly called "Relative Biological Effectiveness (RBE)". The RBE factor is used in experimental work with biological material.

Radiation	QF
γ	1
β	1
α	10
n_t	3
n_f	10

Rad--The unit of absorbed radiation dose equal to 100 ergs/gm of energy deposited in the irradiated material.

Rem (Roentgen Equivalent Man)--That quantity of any type of ionizing radiation which when absorbed by man produces an effect equivalent to the absorption by man of one Roentgen of X or gamma radiation. Rem = rads x QF.

Restricted Area--Any area access to which is controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive material.

Roentgen (R)--The quantity of X or gamma radiation which forms 1 statecoulomb of charge of either sign per 0.001293 grams of air. (1 cc of air at STP).

Specific Ionization--The number of ionization occurring per unit path length in a substance.

Statecoulomb--That quantity of electric charge which, when placed in a vacuum one centimeter distant from an equal like charge, will repel it with a force of one dyne. (Abbreviated: esu)

Unrestricted Area--Any area access to which is not controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials, and any area used for residential quarters.

Nuclide--A species of atom characterized by the constitution of its nucleus.

Positron--A particle equal in mass to the electron and having an equal but opposite charge.

Proton--A particle of the nucleus carrying a positive charge numerically equal to the charge of an electron and with a mass of 1.00758.

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Section III

RADIATION

Radiation in the form of X-rays was discovered in 1895 by Wilhelm Roentgen, a German physicist, who noticed that some fluorescent crystals near a cathode ray tube were made to glow. He named these mysterious rays "X-rays." Soon after this, Henri Becquerel, a French scientist, in 1896 discovered that uranium salts gave off radiation rays much like the X-rays of Roentgen. These rays were shown to expose photographic film even with the film wrapped in paper. Many succeeding years of work revealed the various types of radiation.

A. The Atom

The atom is the basic source of all types of radiation. An atom is the smallest portion of an element which retains the chemical characteristics of that element. It is composed of a nucleus and lighter negatively charged particles called electrons which move around the nucleus in definite orbits. The nucleus may be a single positively charged proton as in the case of hydrogen or a collection of protons and uncharged neutrons. The protons and neutrons have masses about 1,835 times greater than that of the electron. In a neutral atom (un-ionized), the numbers of protons and electrons are equal. The number of protons determines the element. All atoms of hydrogen have the same number of protons (one). Isotopes of an element are determined by the number of neutrons in the nucleus. Thus normal hydrogen (^{1}H) has no neutrons and one proton, while deuterium (^{2}H) which is an isotope of hydrogen has one neutron and one proton and tritium (^{3}H), another isotope of hydrogen, has two neutrons and one proton.

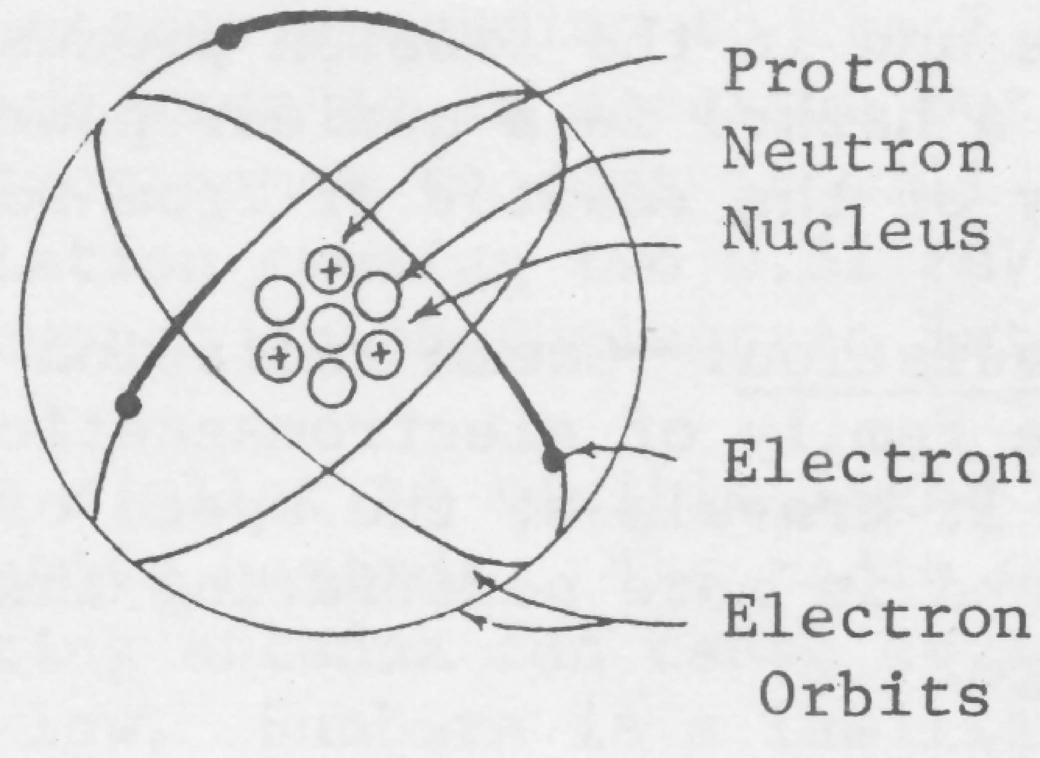


Figure 1

STRUCTURE OF THE ATOM

B. Types of Radiation

The ratio of neutrons to protons determines whether an atom has a stable or unstable nucleus. A radioactive atom has an unstable nucleus which it changes to a stable nucleus by actually ejecting a part of the nucleus in the form of particles. In addition, the ejection of these particles may be accompanied by a release of electromagnetic energy. These ejected nuclear particles and released energy are called radiation. The types of particulate radiation which may be ejected from the nucleus are the beta particle, alpha particle, and the neutron. The electromagnetic energy which sometimes accompanies ejection of the particles is called gamma radiation.

1. Alpha Particle: Alpha radiation may be thought of as a small, fast moving subatomic particle. It is composed of two protons and two neutrons. Neutrons do not carry an electrical charge but each proton has a positive charge, resulting in a net charge of +2 for the alpha particle and a mass of 4 (2 protons and 2 neutrons with a mass of 1 amu each).

2. Beta Particle: The beta particle is also a fast moving subatomic particle which is emitted from the nucleus of a radioactive atom. It is identical to an electron in that it has an electrical charge of -1 and a mass of .0005 amu or 1/1835 the mass of a proton. Note that is has less net charge than the alpha particle and is much lighter. If the nucleus is composed of only neutrons and protons as we have noted, how can a beta particle be emitted? A neutron in the nucleus converts itself to a proton and an electron. The proton remains in the nucleus but the electron is ejected.

3. Neutron: The neutron is also a fast moving subatomic particle with a mass of 1 (approximately equal to the mass of a proton). However, it does not carry an electrical charge and is electrically neutral. The neutron is emitted only from some special artifically produced elements and in the fission process of a reactor. Thus they do not present a hazard in a nuclear power plant except in the immediate vicinity of the reactor or from some special neutron sources.

4. Gamma Radiation: Gamma radiation is released energy, belonging to the same family of electromagnetic radiations as light and radio waves. It travels at the speed of light but has a shorter wave length and is more penetrating than visible light. It has no mass or charge.

C. Interaction in Matter

Alpha and beta particles being electrically charged create electrical forces either of attraction or repulsion with the electrons of atoms in the material through which they pass. These forces can cause an

orbital electron of a neutral atom to be removed. The ejected or removed electron has a negative charge and the affected atom now has one less electron than it has protons so it is positively charged and we have an ion pair formed. This process is known as ionization.

An <u>Alpha</u> particle has a larger charge and greater mass than the beta, and because of this it creates more ion pairs per path length or in other words it gives up its energy quicker. Because of this the range of the alpha is very limited being only a few centimeters in air. It is completely stopped by the dead layer of the human skin or by a piece of paper and does not present an external biological hazard.

<u>Beta</u> particles may travel a hunderd times farther in matter than an alpha of the same energy and consequently may represent an external hazard. However, most beta particles may be stopped by a 1-inch piece of wood or by the lens of a pair of safety glasses.

<u>Gamma</u> radiation like light has no mass or charge. However, it causes ionization by giving up either all or a portion of its energy to an orbital electron of some of the atoms in the material through which it passes. This may be done by the following processes:

1. <u>Photoelectric Effect</u>--All of the gamma ray energy is absorbed by the electron ejecting the electron from its orbit.

2. <u>Compton Scattering</u>--The gamma ray has more than enough energy to eject an electron and the gamma ray continues on at a lower energy after ejecting an electron. The scattered gamma ray may cause further ionization.

3. <u>Pair Production</u>--The gamma ray is of higher energy and actually creates an electron and positron pair as it passes near the nucleus (mass converted to energy according to the $E = mc^2$ formula). A positron has the same mass as an electron but an opposite charge of +1. When the positron comes to rest it will interact with a free electron by annihilation causing two 0.51 MeV X-rays which would then interact by Compton or photoelectric interaction.

Since gamma radiation is similar to visible light and radio waves we might discuss their relative hazards. The radio waves very close to a high-powered transmitting antenna can cause severe burns but their energy per wave is very low. Sunburn is a familiar example of over-exposure to sunlight. The greater danger of gamma radiation is due to its greater penetrating power and higher energy per wave. It can produce damage in deeper portions of the body without any early signs appearing on the body surface.

Neutrons are uncharged particles and as such do not interact directly with the electrons in matter. In a sense the electron cloud provides a shield around the nucleus of an atom shielding out the alpha, beta, and gamma radiations. However, the uncharged neutron is able to penetrate this shield and strike the nucleus. When this occurs, the nucleus may be propelled away from the electron cloud resulting in a positively charged recoil nucleus. The neutron would be deflected but would continue on at a lower energy. This interaction known as elastic scattering might be compared to a billiard ball striking a baseball. The baseball would be propelled forward and the billiard ball deflected and slowed down. This interaction occurs most frequently for fast neutrons striking light atoms such as hydrogen. Water, because of its hydrogen content, thus represents a good material for slowing down neutrons. Once neutrons have been slowed down by elastic scattering and strike the nucleus of another atom instead of knocking the nucleus out of the way, the neutron itself is captured by the nucleus. Some materials such as cadmium and silver are more effective at capturing slow neutrons than other materials and are thus used for shielding and as control rods in reactors because of this property. After a stable nucleus has captured an extra neutron it may become unstable or radioactive emitting beta particles and/or gamma radiation.

Of course in either of these neutron interactions ionization is ultimately produced either by the recoil nucleus or by the emitted beta or gamma radiation.

D. Detection of Radiation

If radiation produces ion pairs, it follows that the amount of radiation present could be measured by collecting and counting the ion pairs produced in a given volume. Most radiation detectors consist of a gas- or air-filled cylindrical chamber with an electric field imposed upon it by using a center-wire anode and the chamber wall as the cathode. The response as related to the voltage maintained across the chamber is shown in Figure 2.

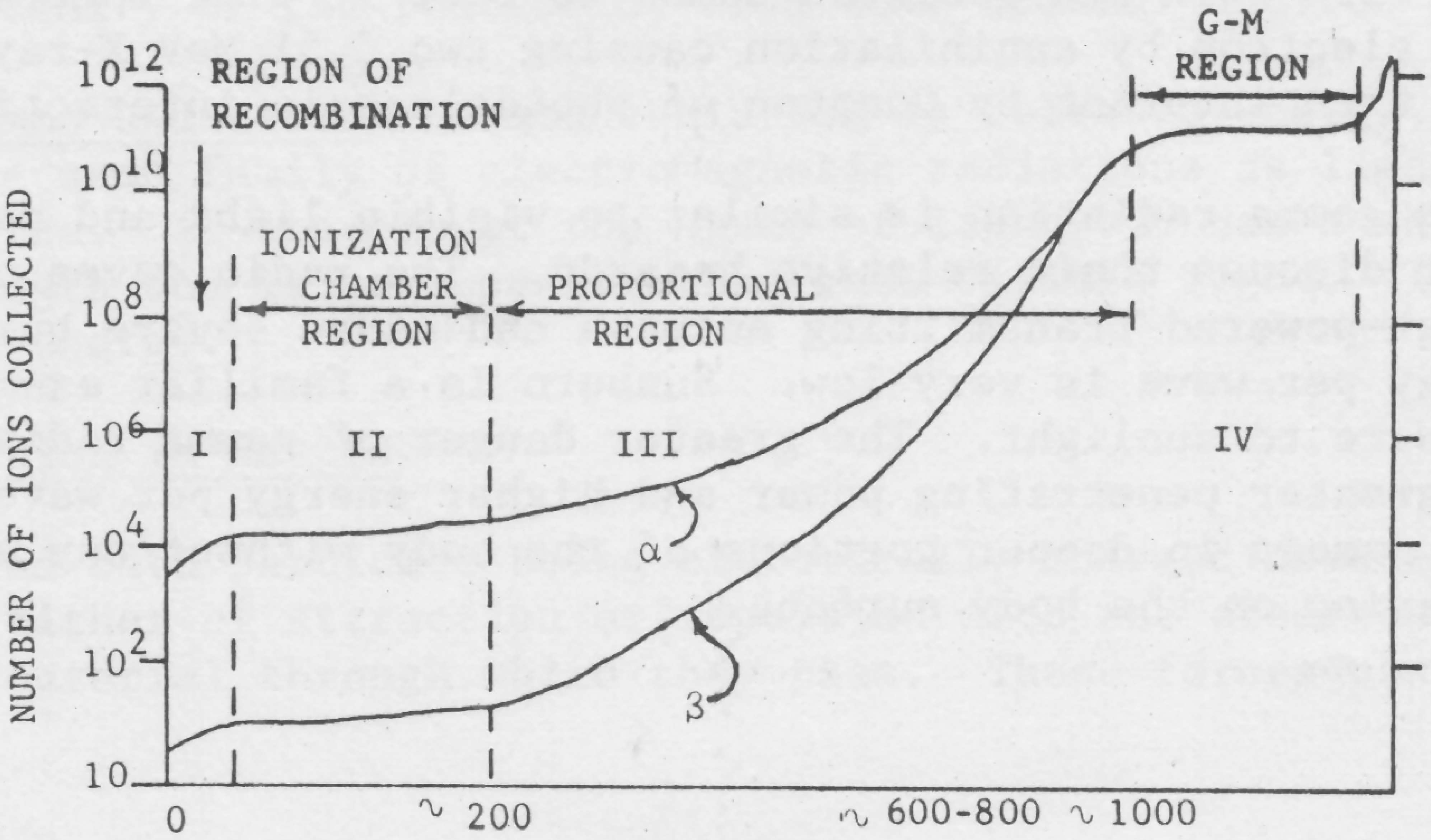


FIGURE 2

AMPLIFICATION IN GAS-FILLED DETECTION CHAMBER

Region I--In this region the electric field is not strong enough to collect all the ions produced. Some of the freed electrons recombine with a positive ion before reaching the anode and thus only a fraction of the original ions is collected. This is the region of recombination.

Region II--The electric field is strong enough to overcome any recombining of the ions, and essentially all the ions are collected resulting in a current flow which is proportional to the amount of radiation causing the ionization. Since the energy expended by the radiation determines the number of ion pairs formed, an instrument operated in this region would give a true dose rate measurement dependent on the energy of the radiation. This is called the ionization chamber region.

Region III--The increased voltage accelerates the electrons so that they gain sufficient kinetic energy to cause further ionization themselves. The number of ions collected is a multiple of the number originally created, the multiplication factor increasing with voltage. This is known as the proportional region as the pulse is proportional to the specific ionization of the incident radiation.

Region IV--At this point the electric field is strong enough so that the creation of one ion pair in the chamber causes enough multiplication so that all the gas in the chamber is ionized resulting in a current pulse. Note that the same size pulse is obtained, since all the gas is ionized, for any type of ionizing radiation. Because of this a G-M counter is very sensitive; however, it does not provide a true indication of dose since the same size pulse is obtained for any energy of radiation.

Three common types of instruments operate on these principles. The "Cutie Pie" and other dose rate instruments operate in the ionization chamber region, the proportional counter in the proportional region and the G-M counter in the G-M region. In addition, scintillation counters which work on a somewhat different principle are sometimes used. When radiation strikes a scintillation crystal, atoms in the material are excited by the radiation resulting in the emission of light. These light flashes which are proportional to the energy of the incident radiation are counted with the aid of a photomultiplier tube and provide an indication of the radiation delivered.

Neutrons do not normally directly ionize; however, the capture interaction may be used to detect them. A detector operated in the proportional region may be filled with boron trifluoride (BF_3) gas. The boron in this gas is effective in capturing slow neutrons which enter the chamber. The excess neutron causes the resulting atom to be unstable resulting in the emission of an alpha particle. The alpha particle causes ionization in the gas within the chamber resulting in a current flow indicating the presence of the neutron which caused the original interaction.

Radiation also causes darkening of film to a degree dependent upon the energy of the radiation. Film badges are thus used to provide a reasonably accurate and reproducible indication of the accumulated radiation received by an individual. Film badges will respond to beta, gamma, and neutron radiation. Alpha particles are stopped by the light-proof paper wrapping over the film used in the badges and are thus not detected by the film. The various types of instruments used for health physics monitoring are shown in appendix I.

Section IV

RADIATION EXPOSURE LIMITS

If radiation causes ionization in human tissue then some damage may result. However, it takes a considerable number of ionizing events to produce any observable effect. In order to control this hazard, standards for protection against radiation have been established by the Nuclear Regulatory Commission. These dose limits apply to all TVA personnel involved in radiation work and are not to be exceeded. These limits for the exposure of plant personnel are given in Table 1.

Conditions for employment for work in a radiation environment include:

1. A known history of previous external and internal occupational radiation exposure. The employee is required to complete TVA Form 17086.

2. Other physical limitations specified by the Director of Medical Services. It is desirable to have a known history of nonoccupational radiation exposure (diagnostic, therapeutic, etc.) significantly exceeding the maximum permissible limits for occupational exposure.

Emergency situations occasionally make it necessary to exceed the prescribed limits in extreme situations. Emergency exposure guidelines for these purposes are given in Table 2. These guidelines must not be used without the full knowledge and consent of the plant superintendent or his duly authorized representative.

Table 1

LIMITING DOSE TO OCCUPATIONAL WORKERS

Body Organ	*Maximum Dose in Rem Quarterly	Annually
Whole body; head and trunk; active blood-forming organs; lens of eyes; or gonads	3	4
Hands, feet, and ankles	18.75	75
Forearms	18.75	30
Skin of whole body	7.5	15
Bone		0.1 μg of ^{226}Ra or its biological equivalent
Other organs	5	15

*Non-TVA personnel shall be limited to the following maximum whole body exposures:

1. 300 mrem/calendar quarter, or

2. 1,250 mrem/calendar quarter if dose records are supplied for the individual(s) for the present calendar quarter. The exposure permitted shall be adjusted so that the total dose received shall not exceed the 1,250 mrem/calendar quarter.

Table 2

EXTREME EMERGENCY EXPOSURE GUIDELINES

Whole Body Dose	Conditions
10 rem	For planned exposure during an emergency situation
25 rem	Taken only to prevent immediate serious damage to plant or personnel
100 rem	May be taken to save a life

Section V

RADIATION PROTECTION

Methods to control radiation exposure are available which form the basis for working safely with all types of radiation. The most important operational methods used for radiation exposure control are given in this section.

A. Time

Radiation is delivered at some exposure rate per unit time and is generally measured in this regard as rem/hr or mrem/hr. It is apparent then that it is possible to limit radiation exposure by limiting the time one spends within a radiation field. Thus, a man working in a radiation field of 300 mrem/hr would receive 50 mrem of exposure if he remained in the area for 10 minutes.

Since most measurements are made in units of dose/hr, it is sometimes necessary to convert to dose rate in minutes to arrive at an acceptable stay time within a radiation field. If we consider the 50 mrem/day operational exposure guideline as the maximum allowed in any one day, the stay time in minutes for various radiation fields may be obtained as follows:

$$T_{50} = \frac{(50 \text{ mrem})\ 60 \text{ min/hr}}{I}$$

I = Radiation intensity (mrem/hr)

T_{50} = Stay time in minutes to receive 50 mrem

Table 3 lists several stay times computed with this formula. Figures 3 and 4 may also be helpful in determining stay times at various dose rates.

Table 3

STAY TIMES FOR 50 MREM EXPOSURE

T_{50} (min)	Dose Rate (mr/hr)
300	10
120	25
90	30
60	50
50	60
40	75
30	100

Another time factor which may be considered as a control technique is the radioactive decay law. If a piece of equipment containing radioactive material of short half-life is a radiation hazard, it may be possible to allow the radioactive material to decay thus lowering the radiation levels. The radiation activity would diminish with time according to the radioactive decay formula:

$$A = A_o e^{-\lambda t}$$

A_0 = activity present at start

A = activity at end of time t

λ = decay constant given by $\lambda = 0.693/T_{1/2}$

$T_{1/2}$ = half-life of radioactive material

t = time elapsed

A graph for this phenomenon is shown in Figure 5 where "Fraction of Activity Remaining" is plotted against "Time in Half-Lives."

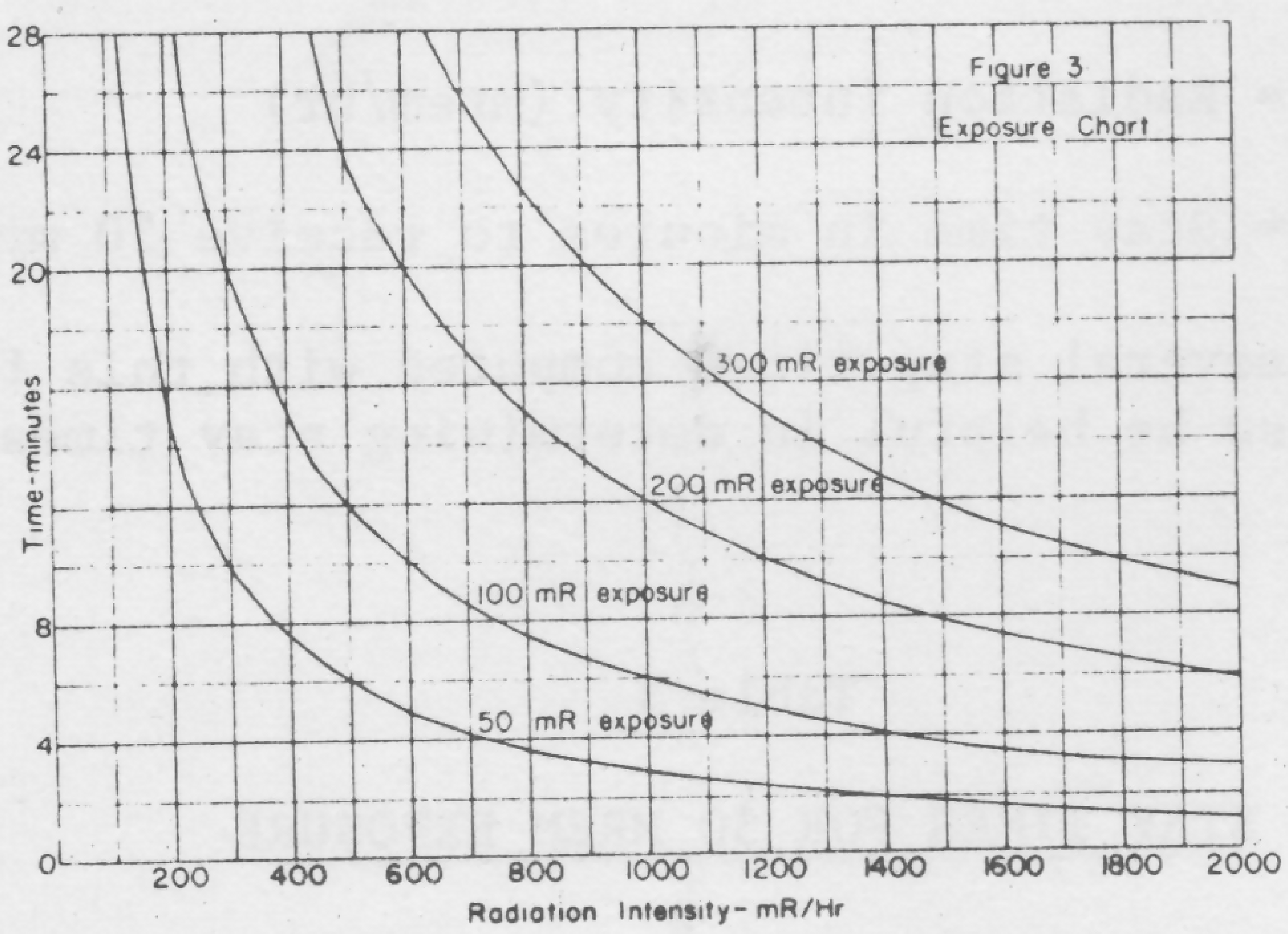


Figure 3

Exposure Chart

Figure 4

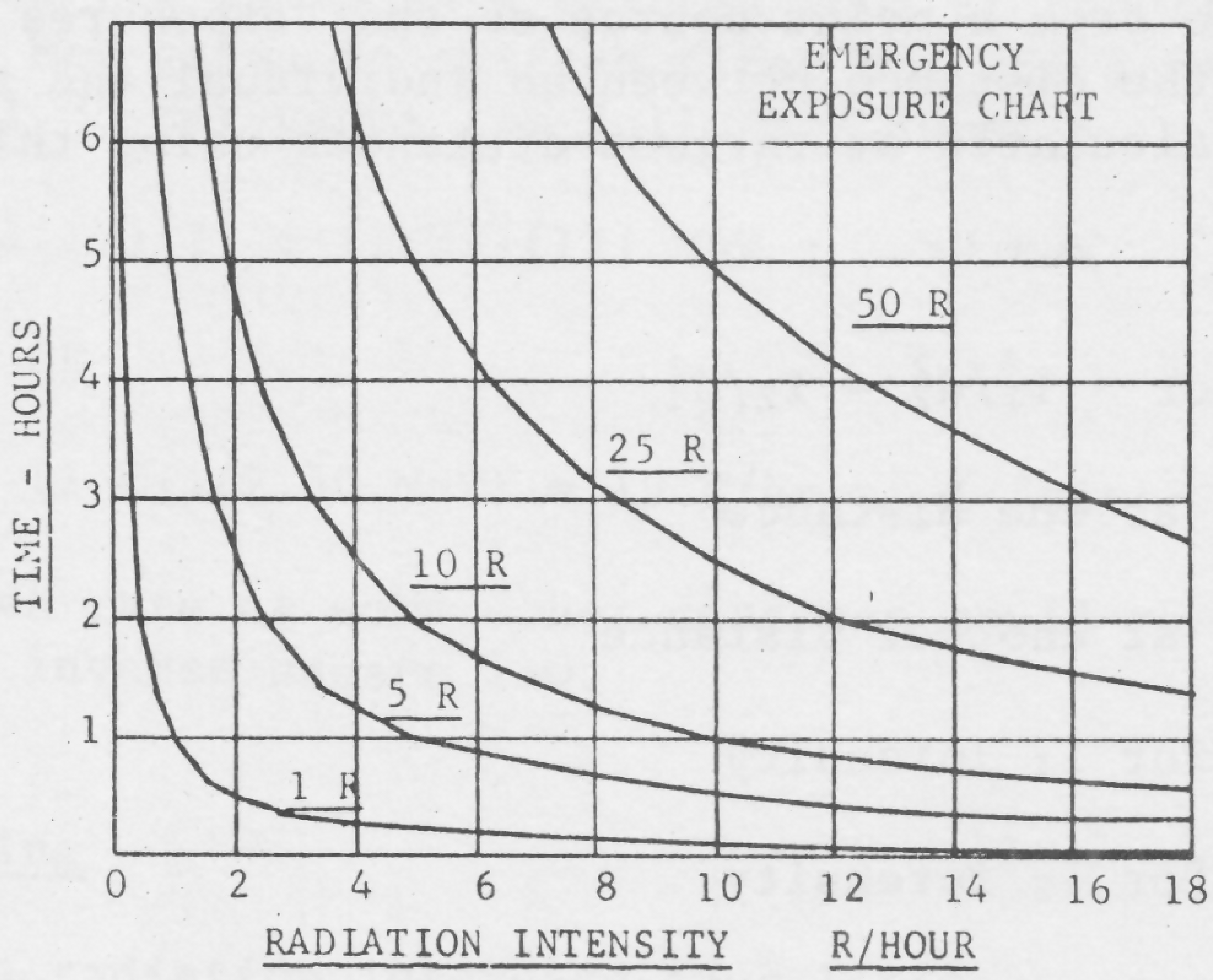
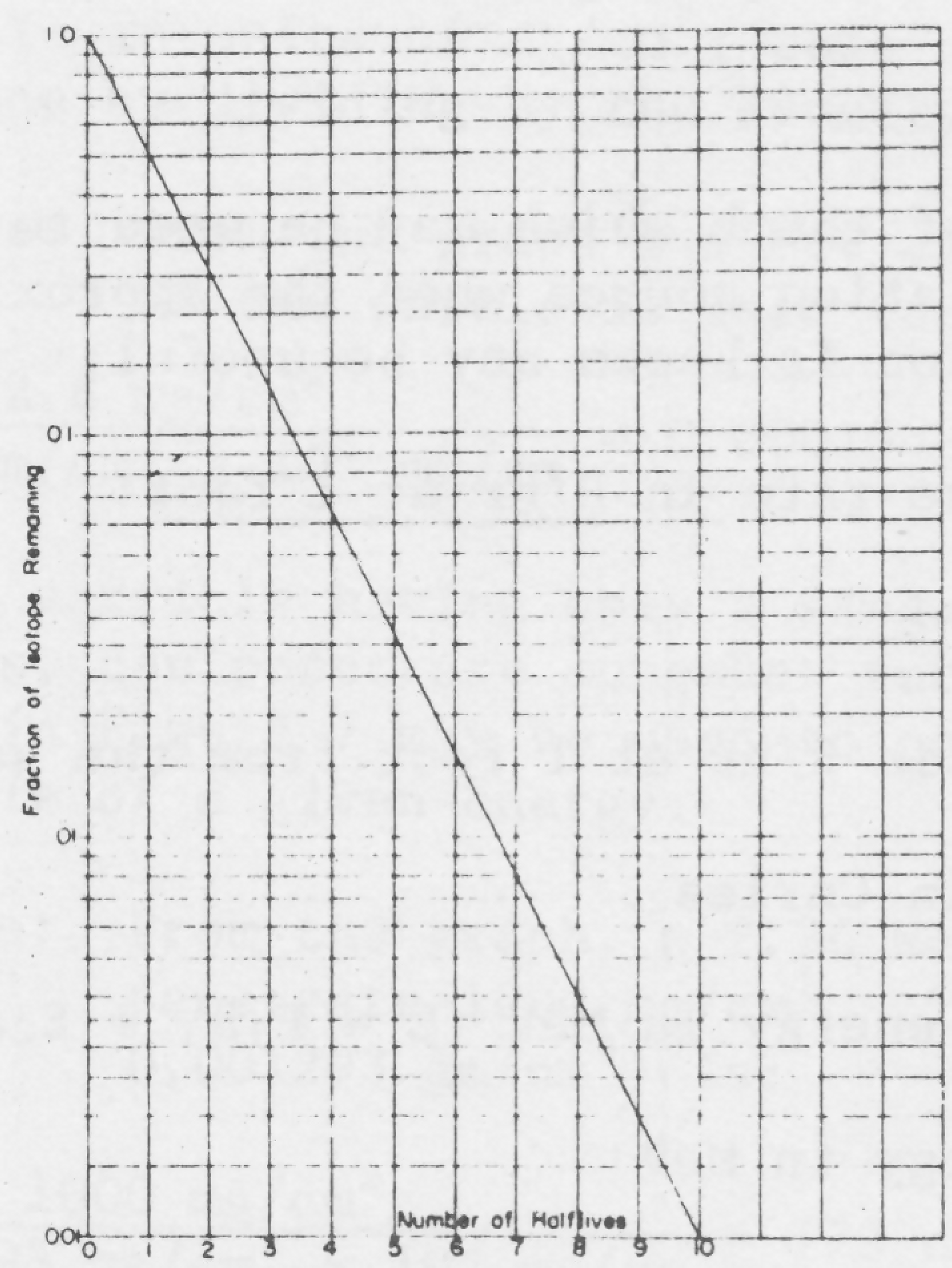


Figure 5



B. Distance

Gamma radiation dose rates are inversely proportional to the square of the distance from a point source so that exposures may be decreased by increasing the distance between an individual and the source. Dose rates may be calculated at various distances using this inverse square relationship.

$I_1 d_1^2 = I_2 d_2^2$ or $I_1/d_2^2 = I_2/d_1^2$

I_1 = intensity at one distance

I_2 = intensity at another distance

d_1 = distance for I_1 intensity

d_2 = distance for I_2 intensity

Example: A point source reads 50 mR/hr at 9 feet. What is the dose rate at 1 foot?

$I_1 d_1^2 = I_2 d_2^2$

$I_1\ (1\ \text{ft})^2 = 50\ \text{mR/hr}\ (9\ \text{ft})^2$

$$I_1 = \frac{(50\ \text{mR/hr})(81\ \text{ft})}{1\ \text{ft}}$$

$I_1 = 4050\ \text{mR/hr}$

In addition, a rule of thumb which may be used to compute the dose rate at 1 foot from a radiation source when the approximate activity and energy of the radiation is known may be useful:

Rule of thumb for dose rate in R/hr at 1 foot:

DR = 6 CE

Where DR = dose rate in R/hr at 1 foot from the source

C = activity in Curies

E = effective energy in MeV ($E = E_1 a_1 + E_2 a_2 + \ldots E_n a_n$)

E_n = γ ray energy in MeV

a_n = % of the disintegrations in which E_n appears

Example: If it is known that an area contains a radiation source of 1 curie of ^{60}Co, what is the dose rate at 1 foot from the source?

^{60}Co has two gamma rays emitted 100% of the time per disintegration. A 1.17 MeV gamma is emitted first but the atom still has excess energy and a 1.33 MeV gamma ray follows. Thus:

$$E = [(1.17)(1) + (1.33)(1)] \text{ MeV} = 2.50 \text{ MeV}$$

$$DR = 6 \text{ CE}$$

$$DR = 6 \ (1 \text{ Ci})(2.50 \text{ MeV}) = 15 \text{ R/hr at 1 foot}$$

The dose rate at some other distance could then be determined by use of the inverse square law.

C. Shielding

Because radiation interacts thus losing energy in any material through which it passes, radiation intensity may be reduced or eliminated altogether by placing some material (shielding) between the radiation source and personnel. The radiation then gives up its energy in the shield. Methods of shielding and some indication of how far various types of radiation penetrate are given in this part.

1. Because of its mass and charge an alpha particle does not penetrate very far in matter. A graph showing the relation between energy of the particle and range of the particle is shown in Figure 6. Range is in units of mg/cm^2; this can be converted to units of distance by dividing by the density of the shielding material.

   Example: From the graph a 4 MeV alpha will penetrate 2.8 mg/cm^2. If the shield is lead (density = 11.3 gm/cm^3) the range is:

$$\frac{2.8 \text{ mg/cm}^2}{11.3 \text{ gm/cm}^3 \times 10^3 \text{ mg/gm}} = 0.00025 \text{ cm}$$

2. A beta particle having only a singular charge and much lighter in mass, can penetrate somewhat further in materials. The graph shown in Figure 7 may be used to compute the range of a beta particle of a given energy.

   Example: From the graph, a 2.26 MeV beta emitted from ^{90}Y will penetrate 1000 mg/cm^2. The range in air (density = 0.001293 gm/cm^3) is:

$$\frac{1000 \text{ mg/cm}^2}{0.001293 \text{ gm/cm}^3 \times 10^3 \text{ mg/gm}} = 773 \text{ cm}$$

If lead (density 11.3 mg/cm^2) is used as a shield, the range is:

$$\frac{1000\ mg/cm^2}{11.3\ gm/cm^3 \times 10^3\ mg/gm} = 0.09\ cm$$

3. Gamma rays do not have a definite range as charged particles do. Gamma rays are very penetrating and thus represent a significant external radiation hazard. Large masses of dense material such as lead or concrete are required to shield gamma rays. Its penetration is described by the relationship $I = I_o e^{-\mu x}$

where I_o = the number of incident rays

I = the number of rays penetrating the distance x through the shield

μ = the linear absorption coefficient (fraction of gammas stopped per unit length)

Linear absorption coefficients for various materials are shown in Table 4, and Table 5 gives half-value layers for these materials. The half-value layer is the thickness of a material which will attenuate or reduce the incident radiation beam to one-half of its incident value.

4. Neutrons are very penetrating if not shielded correctly. Since neutrons are uncharged and thus do not interact with electrons, dense material such as lead does not provide an effective shield. Material rich in hydrogen such as paraffin or water or other light elements such as carbon is used to slow neutrons down because more energy is given up in a collision between a neutron and a light nucleus. Thus the light hydrogen nucleus is very effective in slowing neutrons. After neutrons reach thermal energies they are more readily absorbed by the ordinary shield materials such as iron and concrete. (Neutrons are also captured by hydrogen atoms once they have slowed to thermal energies and a water shield thick enough to slow fast neutrons is usually thick enough to absorb those neutrons.) Neutron absorption is given by the relationship:

$$I = I_o e^{-\sigma N X}$$

I_o = incident neutron beam

I = neutrons which penetrate the shield of thickness X

σ = cross section for neutron absorption

N = number of $atoms/cm^3$

Figure 6

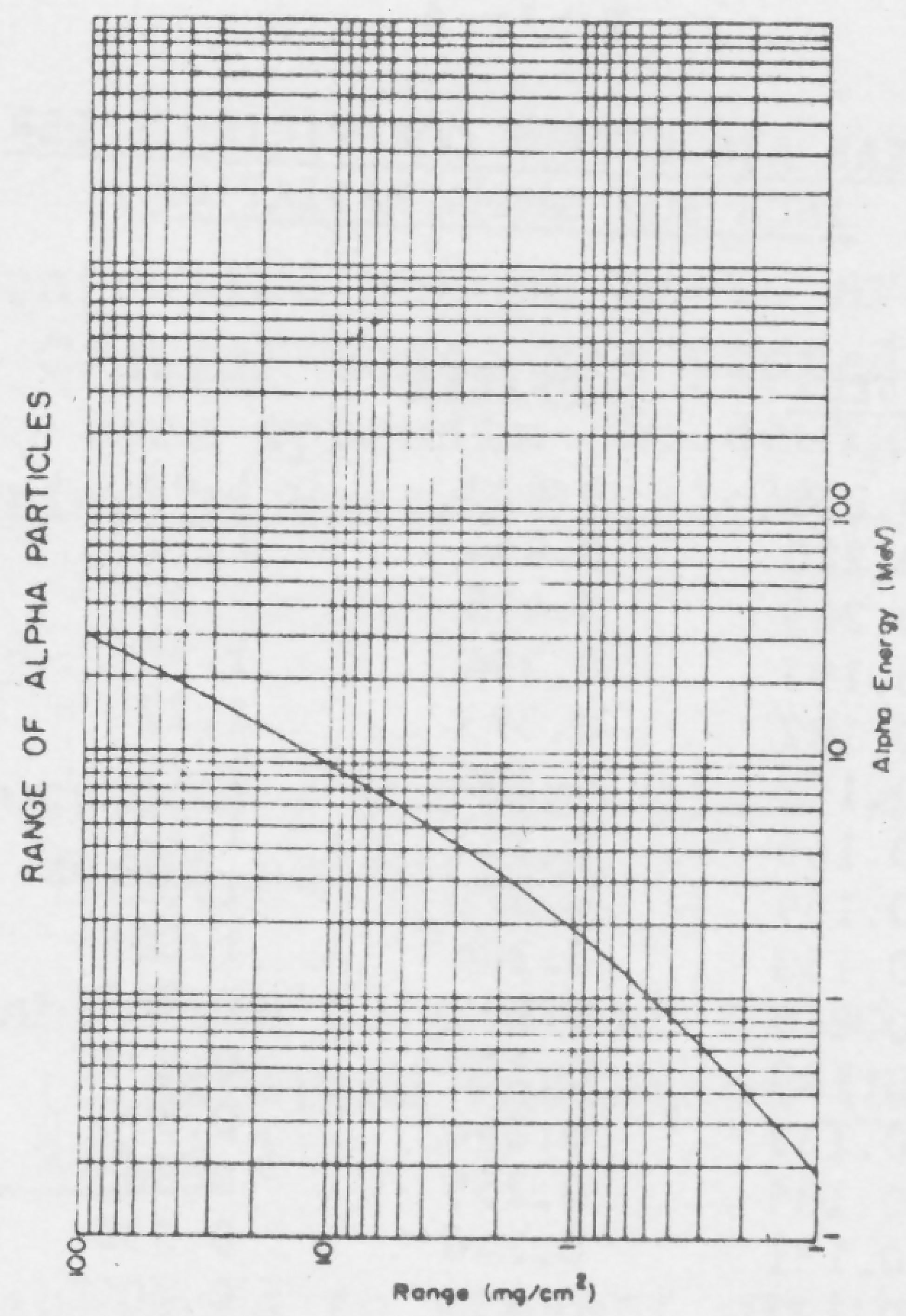


Figure 7

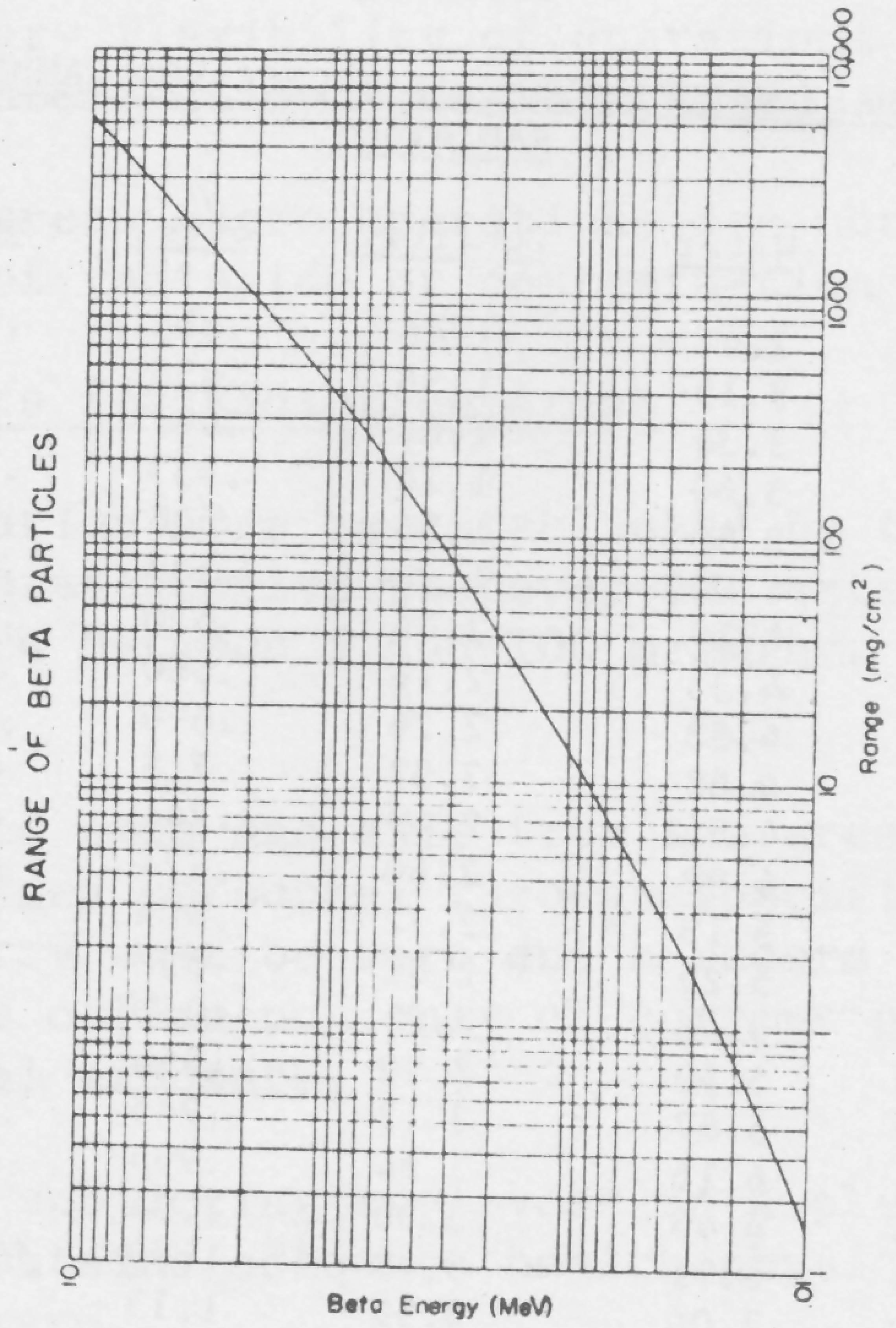


Table 4

LINEAR ABSORPTION COEFFICIENTS PER INCH FOR GAMMA RADIATION

MeV	Water	Concrete	Steel	Lead
0.5	0.238	0.473	1.63	4.36
0.6	0.220	0.444	1.52	3.62
0.7	0.205	0.418	1.39	3.02
0.8	0.193	0.394	1.30	2.54
0.9	0.182	0.373	1.22	2.20
1.0	0.173	0.354	1.16	1.98
1.1	0.166	0.337	1.10	1.82
1.2	0.159	0.321	1.05	1.71
1.3	0.153	0.306	1.005	1.61
1.4	0.148	0.292	0.965	1.52
1.5	0.143	0.278	0.931	1.45
1.6	0.139	0.266	0.895	1.39
1.7	0.135	0.255	0.863	1.34
1.8	0.131	0.246	0.830	1.29
1.9	0.127	0.238	0.800	1.24
2.0	-0.124	0.232	0.775	1.21
2.2	0.118	0.222	0.733	1.16
2.4	0.113	0.214	0.697	1.13
2.6	0.107	0.206	0.666	1.12
2.8	0.103	0.199	0.638	1.11
3.0	0.099	0.193	0.613	1.11

Table 5

HALF-VALUE LAYERS IN INCHES FOR GAMMA RADIATION

MeV	Water	Concrete	Steel	Lead
0.5	2.91	1.46	.425	.159
0.6	3.15	1.56	.456	.191
0.7	3.38	1.66	.497	.230
0.8	3.60	1.76	.533	.273
0.9	3.80	1.86	.568	.315
1.0	4.00	1.96	.597	.350
1.1	4.19	2.06	.630	.381
1.2	4.35	2.16	.660	.405
1.3	4.53	2.26	.690	.430
1.4	4.68	2.37	.718	.456
1.5	4.85	2.49	.744	.478
1.6	4.99	2.60	.774	.499
1.7	5.13	2.72	.803	.517
1.8	5.29	2.82	.835	.537
1.9	5.46	2.91	.866	.559
2.0	5.59	2.99	.894	.573
2.2	5.87	3.12	.945	.597
2.4	6.16	3.24	.994	.613
2.6	6.45	3.36	1.04	.619
2.8	6.71	3.48	1.09	.625
3.0	7.00	3.59	1.13	.625

The half layer is the thickness of material which will reduce the dosage rate of radiation passing through it by one-half of its incident value.

D. Zoning

Special zones or controlled access areas are used for radiation protection purposes. Control zones are posted with appropriate signs, tags, tape, or rope (see appendix II) designating the type of control related to the particular hazard involved.

1. Types of Zones

For control purposes a nuclear plant may be divided into essentially four types of zones as follows:

a. Zones established to prevent or minimize the exposure of personnel to external radiation (Radiation Areas and High Radiation Areas.)

b. Zones established to prevent or minimize the contamination of employees or spread of contamination (Contamination Areas and Airborne Radioactivity Areas). These particular zones are discussed more thoroughly in the section on contamination.

c. Zones established as a type of buffer zone where operations are restricted for control purposes (Regulated Areas). Since they are adjacent to radiation and contamination areas, the movement of personnel and equipment must be controlled. A regulated zone is primarily a "convenience" area to allow the necessary flexibility of operations and still keep radiation and contamination zones contained.

d. Clean areas where operations are not restricted for the purposes of radiation or contamination control.

2. Requirements for Radiation Areas

a. A Radiation Area is established by the health physicist or his representative whenever the external dose rates in an area are between 5 and 100 mrem/hr. Appropriate signs are posted.

b. Entrance into and exit from the areas may be made only by authorized personnel through specified portals. Personnel dosimetry must be worn and a record maintained in the health physics office not only of current but of any previous occupational exposure.

c. Before subjecting employees to a planned exposure, the supervisor obtains adequate health physics consultation to evaluate the hazard.

d. A <u>Special Work Permit</u> is required if a work assignment may result in an individual exposure greater than 50 mrem in any one day or 100 mrem in a work week or result in an exposure field of 100 mrem/hr.

3. <u>Requirements for High Radiation Areas</u>

a. A High Radiation Area is established by the health physicist or his representative whenever the external dose rates in an area are greater than 100 mrem/hr. Appropriate signs are posted.

b. Entrance into high radiation areas requires a Special Work Permit and a continuously indicating dose rate monitor while people are in the area.

c. High Radiation Areas greater than 1000 mrem/hr are maintained locked except during periods when access to the area is required with positive control over each entry.

d. No individual shall be prevented from leaving a High Radiation Area.

4. <u>Requirements for Regulated Areas</u>

a. Regulated areas may be established by the health physicist or his representative in work areas surrounding, adjacent to, or connecting radiation or contamination areas.

b. Regulated areas are accessible to all authorized plant personnel.

Section VI

Special Work Permit

Special Work Permits are required for all work where employees may be exposed to radiation or contamination exceeding the working guidelines of 50 mrem/day, or for all work in Airborne Radioactivity Areas, Contamination Areas, High Radiation Areas, and at the discretion of the health physicist. The following table lists the necessary approvals for issuance of a Special Work Permit based on exposure levels.

Table 6

Approvals Required for Special Work Permits

Whole Body Dose or Dose Rate	Approval Required to Exceed Guidelines
50 mrem/day or 100 mrem/hr	Health physicist or authorized representative. Employee's supervisor. Shift engineer.
50% of remaining allowable quarterly dose, 750 mrem/day, 1 rem/hr	Above and health physics supervisor.
50 rem/hr	Above and the plant superintendent.
5 rem/yr	Chief, Nuclear Generation Branch. Chief, Radiological Hygiene Branch

A. Procedure for Issuance of a Special Work Permit (SWP)

1. Each supervisor consults with the health physics supervisor or authorized representative when work is to be performed in a radiation or contamination zone.

2. The health physics representative performs radiation surveys and determines the need for SWP's.

3. The employee's supervisor completes the application portion of the SWP giving description of the work to be performed, including location, list of employees involved, duration, and special tools or equipment required. His signature is required.

4. The health physics supervisor or representative prescribes the protective clothing and equipment, work limitations, time restrictions and approves the permit. Reference by number should be made to related SWP's.

5. The shift engineer reviews and approves the SWP.

6. A copy of the SWP is prominently displayed or readily available at the work site.

7. The employee's supervisor ensures that work is performed in accordance with the instructions prescribed on the SWP.

8. The health physics supervisor or representative is informed of any changes in work conditions which might affect the requirements previously established by the SWP.

9. An SWP is valid for only the shift during which it was issued. A new permit or a Supplementary Time Sheet must be obtained for work continuing into another shift. A Supplementary Time Sheet should refer by number to the related SWP and be signed by the requestor and health physics technician.

10. Revisions in an SWP may be made only with the approval of a health physics representative and the appropriate supervisors for the shift during which the revisions are made.

11. A copy of all completed SWP's and Supplementary Time Sheets is returned to the record file of the health physics supervisor.

12. The plant health physicist may extend the SWP beyond the shift during which it was issued for a period not to exceed one week. There must be a Supplementary Time Sheet issued each shift during this period when entry into the area is to be made. The shift engineer must be notified of the work to be performed and the SWP number.

13. A Special Work Permit-Routine may be used for certain routine and repetitive work activities and takes the place of the SWP. In no case may it be used for any maintenance, fuel handling, or in-service inspection activities. It must be reviewed and recommended for approval by PORC and approved for issuance by the plant superintendent. A Special Work Permit-Routine can be applied for all situations except for the following where an SWP is required.

    1. Airborne radioactivity concentration exceeds μPC.

    2. The whole body radiation dose rate exceeds 500 mrem/hr.

    3. An individual performing the work is likely to receive a dose in excess of 50 mrem in a day.

    4. The area is posted as SWP Area.

Entry requirements will be based upon surveys made by the health physicist or his representative. Individuals permitted to enter high-radiation areas under this procedure must notify health physics prior to entry and after exiting, and be trained and use a portable radiation rate measuring device for self-monitoring purposes. A list of individuals authorized by the plant superintendent to enter high-radiation areas in accordance with this procedure will be maintained.

14. A Continuing Special Work Permit.

    The Continuing SWP can be used up to 7 days and need only be signed one time during that time period. It consists of three forms as follows:

    1. Continuing Special Work Permit--A special form on which the appropriate supervisor describes the location and type of work to be done. Approvals are obtained as required for a normal SWP. A space for remarks or special instructions is also available.

    2. Continuing Special Work Permit Supplementary Sheet--The Continuing Special Work Permit Supplementary Sheet is filled out each shift that work continues, by the plant health physicist or his representative prescribing the work limitations and radiation protection measures to be applied and other appropriate information.

    3. Supplementary Time Sheet--A Supplementary Time Sheet may be used for additional space where more persons enter the area than there are spaces on the Continuing Special Work Permit Supplementary Sheet.

Section VII

Contamination

Radiation has been defined as the particulate or electromagnetic emissions from radioactive atoms. Contamination is the presence of these radioactive atoms in an unwanted location. The physical states of contamination may be either solid (dust), liquid, or gaseous. It is through the transfer of radioactive material that personnel or equipment may become contaminated. It is not the contamination itself which presents the hazard but the radiation emitted from it. Thus measures to limit the amount of contamination and techniques to control the spread of contamination are important as well as methods to remove contamination (decontamination).

A. Contamination Areas and Limits

Contamination areas are areas established to prevent or minimize the contamination of employees, equipment, or the environs. A contamination area is established by the Health Physics Office whenever surface contamination levels exceed those given in Table 7. These areas are posted with appropriate warning signs.

Table 7

Criteria for Establishing a Contamination Zone
Based on Surface Contamination

Types of Radiation	Direct Reading	Transferable
Alpha	300 dpm/100 cm^2	30 dpm/100 cm^2
Beta-Gamma	*0.25 mrad/hr (1500 cpm)	1,000 dpm/100 cm^2

*Direct survey will normally be performed with a G-M survey instrument which gives an indication in counts per minute (cpm) so that the number in parenthesis may be used as the limit in this case for operational purposes.

Operations which result in appreciable dusting or turbulent air movement and which could lead to excessive contamination of persons, plant areas, and the environment are restricted and require health physics evaluation.

Special contamination area clothing such as coveralls, gloves, shoecovers or hoods are used for work in these areas. Control techniques require establishment of maximum contamination limits for removal of persons, clothing, or other items from a contamination area.

These limits then define allowable contamination levels for particular situations throughout the plant. When items, personnel, or areas are found which exceed the limits given in Table 8, a health physics representative should be notified. The health physics representative will then make arrangements for decontamination and/or establishment of additional control techniques.

1. Requirements for Contamination Areas

a. Contamination limits are established by the health physicist or his representative and are observed in all plant areas and operations.

b. Operations which result in appreciable dusting or turbulent air movement and which could lead to excessive contamination of persons, plant areas, and the environment are restricted and require health physics evaluation.

c. Appropriate zoning and personnel exposure controls shall be established for any area where plant personnel might encounter contamination levels in excess of operating limits (see Table 7 and Table 8).

d. Internal deposition of radionuclides is not permitted to exceed the maximum permissible body burdens as recommended in NBS Handbook 69.

e. All work in contamination areas requires an SWP.

f. Protective clothing and equipment as specified by the SWP or as posted are required. If requirements are not posted contact a health physics representative.

g. Entrance into and exit from contamination areas are made only through specified portals.

h. Personnel and equipment going from a contamination area to a regulated area should be monitored as soon as practical after leaving the contamination area. The survey should indicate contamination to be within the prescribed limits. All equipment being transferred to a clean area must be tagged with a Contamination and Radiation Clearance Tag specifying that it has been monitored and meets the prescribed limits.

i. No lunchroom is permitted within a contamination area or regulated area. Eating, smoking, and drinking are prohibited in contamination areas. Smoking in regulated areas is permitted only in specified areas.

j. Open cuts, puncture wounds, skin rashes, and infection must be adequately protected prior to entering a contamination area.

k. The method of cleanup or decontamination prior to leaving a contamination area or regulated area is prescribed by a health physics representative.

Table 8

Maximum Contamination Limits

Item	Direct Survey: Alpha (dpm/100 cm^2)	Direct Survey: Beta-Gamma (mrad/hr)*	Transferable (Smear): Alpha (dpm/100 cm^2)	Transferable (Smear): Beta-Gamma (dpm/100 cm^2)
Skin of whole body	200	0.05 (300 cpm)	Not detectable	
Hands	200	0.05 (300 cpm)	Not detectable	
Personal clothing				
Shoes				
Inside	300	0.05 (300 cpm)	Not detectable	
Outside	300	0.05 (300 cpm)	Not detectable	
Clothing	300	0.05 (300 cpm)	Not detectable	
C-Zone clothing	300	0.75 (4500 cpm)	Not detectable	
Plant surfaces				
Regulated areas	300	0.25 (1500 cpm)	30	1,000
Nonzoned areas	300	0.05 (300 cpm)	30	200
Clearance items**	300	0.05 (300 cpm)	30	200

*Direct survey in cpm will normally be performed with a G-M survey instrument equipped with what is conventionally called a pancake probe, with a window of 1-3/4" diameter. The reading will be made as close as possible without actually coming in contact with the item being surveyed.

**Clearance items apply to items such as tools and equipment being transferred to clean shops, storerooms, etc., or for release to the general public. These items must be accompanied by a Contamination and Radiation Clearance Tag (see section on Signs and Tags).

B. Contamination Area Clothing

Contamination area clothing consists of protective apparel provided for use by employees performing work in contamination areas. Items such as coveralls, jackets, laboratory coats, caps and hoods, shoe covers, plastic suits, rubber overshoes, and gloves may be included. These items are specifically designated for contamination area use and coveralls, jackets, etc., will be marked with the word "Contamination" or with the letter "C" across the back. Some equipment such as tongs, masking tape, wrenches, etc., may also be designated for use only in contamination areas.

1. Requirements for Use of Protective Clothing

   a. Contamination area clothing may be worn only in a contamination area or a regulated area.

   b. Unauthorized alteration of contamination area clothing is prohibited.

   c. Requirements concerning use of contamination area clothing and equipment within a contamination area are specified on the particular SWP required for work in the contamination area.

   d. Contamination area clothing is monitored for radioactive material as needed during work and upon completion of work.

   e. Used contamination area clothing must be kept segregated from clean clothing and not allowed to accumulate for extended periods of time.

   f. Unused contamination area clothing or equipment must be surveyed by a health physics representative and tagged with a green Contamination and Radiation Clearance Tag before being returned to the main storeroom.

   g. Contamination levels for laundered contamination area clothing being returned to the bins are listed in Table 8.

   h. Clothing that cannot be economically decontaminated or stored for radioactive decay must be considered solid radioactive waste and is disposed of accordingly.

   i. Contamination Area Change Areas are used for clothing changes when preparing for or leaving work in contamination areas.

      (1) Contaminated tools and equipment should not be permitted to accumulate in the area.

      (2) The change area is routinely surveyed by a health physics representative to ensure contamination and radiation limits are maintained.

C. Decontamination

The hazard from contamination may be eliminated by prompt removal of contamination thus removing the source of radiation. If the contamination is on equipment, the objective is to return the item or entire area to normal use. In the case of personnel, it is necessary to decontaminate to limit radiation exposure and avoid the possibility of inhalation, ingestion, injection, or absorption of radioactive materials.

1. Requirements for Personnel Decontamination Procedures

   a. Contamination of personnel is reported to a health physics representative.

   b. The health physics representative shall monitor and decontamination procedures will be accomplished under his direction.

   c. In general, the following procedures may be used for personnel decontamination.

      (1) Remove any clothing or equipment known to be contaminated before attempting to determine levels of skin contamination.

      (2) Decontaminate with soap and water any spots or areas of the body found to be more significantly contaminated than surrounding areas. This spot cleaning is necessary to prevent the spread of contamination to clean areas of the body by more general cleaning.

      (3) If contamination is general over the body surfaces, take a thorough shower placing particular emphasis on hairy areas, hands, and fingernails.

2. Requirements for Equipment Decontamination

   a. Area and equipment decontamination methods follow two broad avenues of attack, mechanical and chemical. The main mechanical methods are vacuum cleaning, sandblasting, surface removal, flame cleaning and scraping. Principal chemical methods are water flushing, steam cleaning, solutions of water and detergents or soaps, acids, caustics and solvents.

   b. Certain phases (such as sandblasting, steam cleaning, etc.) of these decontamination processes are potentially hazardous to personnel, and health physics practices include the use of protective clothing, respiratory devices, localized shielding, isolation of an area, and disposal of waste residue. Thus, a health physics representative will advise as to decontamination procedures and protective measures to be taken for equipment decontamination.

   c. Three other methods of handling contaminated items involve (1) the storage for radioactive decay purposes, (2) fix and cover up the contamination by some method such as painting, and (3) disposal, either of parts or the whole.

Section VIII

AIRBORNE RADIOACTIVITY

A special form of contamination occurs when radioactive material becomes airborne. This can occur as a result of a dusty operation, radioactive gas line leaks, a steam leak involving radioactive contaminants, and etc. Another example which might be considered is the heating or welding of a long pipe suspected of being heavily contaminated on the inside. Heating and vaporization resulting in airborne radioactivity pose a hazard to the person performing the task as well as to personnel at other openings in the pipe who may not be aware of the hazard.

A. Airborne Radioactivity Areas and Limits

In order to control these types of hazards, Airborne Radioactivity Areas may be established by the health physicist. The prescribed limits for establishment of such an area are given in Table 9 and are based on exposure to the MPC for a 40-hour work week. These areas will be posted with signs and tags indicating restricted entrance with protective equipment required.

Table 9

Criteria for Establishing an Airborne Radioactivity Area

Type of Radiation	Airborne Contamination (μCi/cc Unidentified Radionuclides)*
Alpha	7×10^{-11}**
Beta-Gamma	3×10^{-9}**

*If the identity of the radionuclides is known, the concentration limits in 10 CFR 20, Appendix B, shall apply.

**Isotopes with more restrictive MPC values would be present in such small quantities that they can be considered not present in any airborne activity found at an LWR.

B. Respiratory Protection

In an area containing airborne radioactivity, the most serious hazard involves the inhalation of radioactive material into the lungs. This material may then be assimilated by the body and retained in some organ of the body. This of course results in radiation exposure to the lungs and any other organs involved. Thus it is necessary to provide some sort of respiratory protection to control this hazard and still allow work to be performed in Airborne Radioactivity Areas.

There are many types of respiratory protection devices with some having a higher degree of protection than others. The degree of protection afforded by a respirator is given in terms of Protection Factors. A Protection Factor (PF) is defined as the ratio of the concentration of airborne radioactive material outside the respirator to that inside the facepiece under conditions of use. PF's range from 5 for a high efficiency half-face dust respirator to 1,000 for a positive pressure, self-contained breathing apparatus. Appendix III gives examples of the various type respirators supplied along with the PF's for each.

C. Requirements for An Airborne Radioactivity Area

1. An SWP is required for any entry into an Airborne Radioactivity Area.

2. Contamination area clothing and respirators as specified by the SWP. This requires that a health physics representative be contacted. The concentration of air activity may be determined through air sampling and subsequent counting by the health physics representative.

3. Entrance and exit are made only through specified portals.

4. All personnel and equipment leaving an Airborne Radioactivity Area must be monitored and meet the contamination limits of Table 8. All equipment being transferred to Clean Areas must be tagged with a Contamination and Radiation Clearance Tag.

5. All the requirements for work in Contamination Areas are applicable.

Section IX

INJURIES IN CONTAMINATION OR RADIATION AREAS

Because of the hazard from internal deposition of radioactive material resulting from contamination of wounds and from external radiation to a person immobilized in a high radiation field, special attention is given to injuries occurring in Contamination or Radiation Areas.

Note: In general the following actions should be instituted; however, in case of severe injuries, lifesaving measures take precedence over contamination control. The health physics representative, medical office, and shift supervisor shall be notified of all injuries as soon as possible.

Requirements for Handling Injuries in Contamination or Radiation Areas

A. Minor Injuries

In all cases of minor injury in the controlled areas, personnel will immediately leave work area observing all zoning regulations and contact health physics to check wound for contamination.

1. If no contamination exists, patient will be sent to medical office for treatment.

2. If contamination is found, decontamination will be attempted under health physics supervision. Flush wound with domestic tap water and promote bleeding by massaging toward the injury.

3. Bioassay samples or whole body counting may be necessary to check for possible uptake of radioactive contamination.

B. Major Illness or Injury

1. Check the dose rate in the area around the patient. If the dose rate is greater than 2 rem/hr, remove the patient to an area with a low dose rate or provide temporary shielding to reduce exposure. The patient should also be moved if an airborne radioactivity or a serious contamination hazard exists.

2. If no radiological hazard exists, do no move the patient until approved by a medical office representative.

3. Get the patient out of the contaminated area quickly if his condition allows movement, remove protective clothing and decontaminate, if possible, without aggravating the patient's condition. If the injury is severe, immediate medical attention takes precedence over contamination control.

4. Determine extent of injury or illness, if possible, and perform emergency first aid. If a wound is grossly contaminated, a tourniquet may be applied to prevent rapid assimilation of contamination by the blood stream. Application of a tourniquet is not recommended for this purpose except in the most severe circumstances.

Section X

HANDLING, STORAGE, TRANSFER OF RADIOACTIVE MATERIALS

Radioactive material-handling operations are conducted so as to minimize personnel exposure and the release and spread of radioactive contamination. This includes storage, transfer, and use within the plant and shipments of radioactive materials to off-area locations.

The U.S. Department of Transportation (DOT) has the responsibility for regulation of the shipment of radioactive materials in the United States. These regulations are published in the Federal Register, Title 49, Parts 170-190. The following sections provide a summary of some of these regulations applicable to shipments to or from nuclear power plants.

A. Labeling of Radioactive Material Packaged for Transport

There are three labels for radioactive materials that are being shipped offsite specified by the DOT.

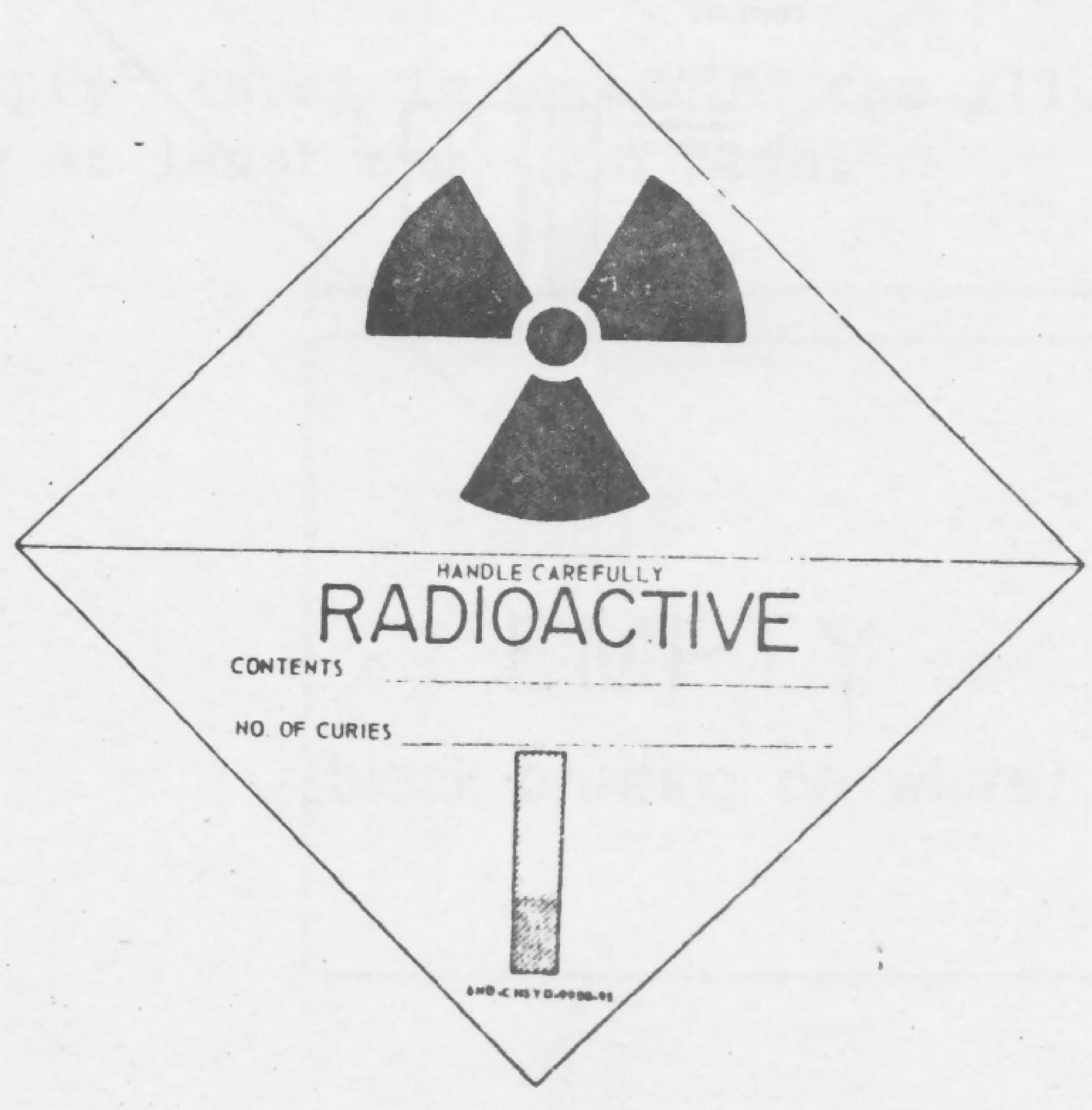
The three labels are:

1. Radioactive White I
2. Radioactive Yellow II
3. Radioactive Yellow III

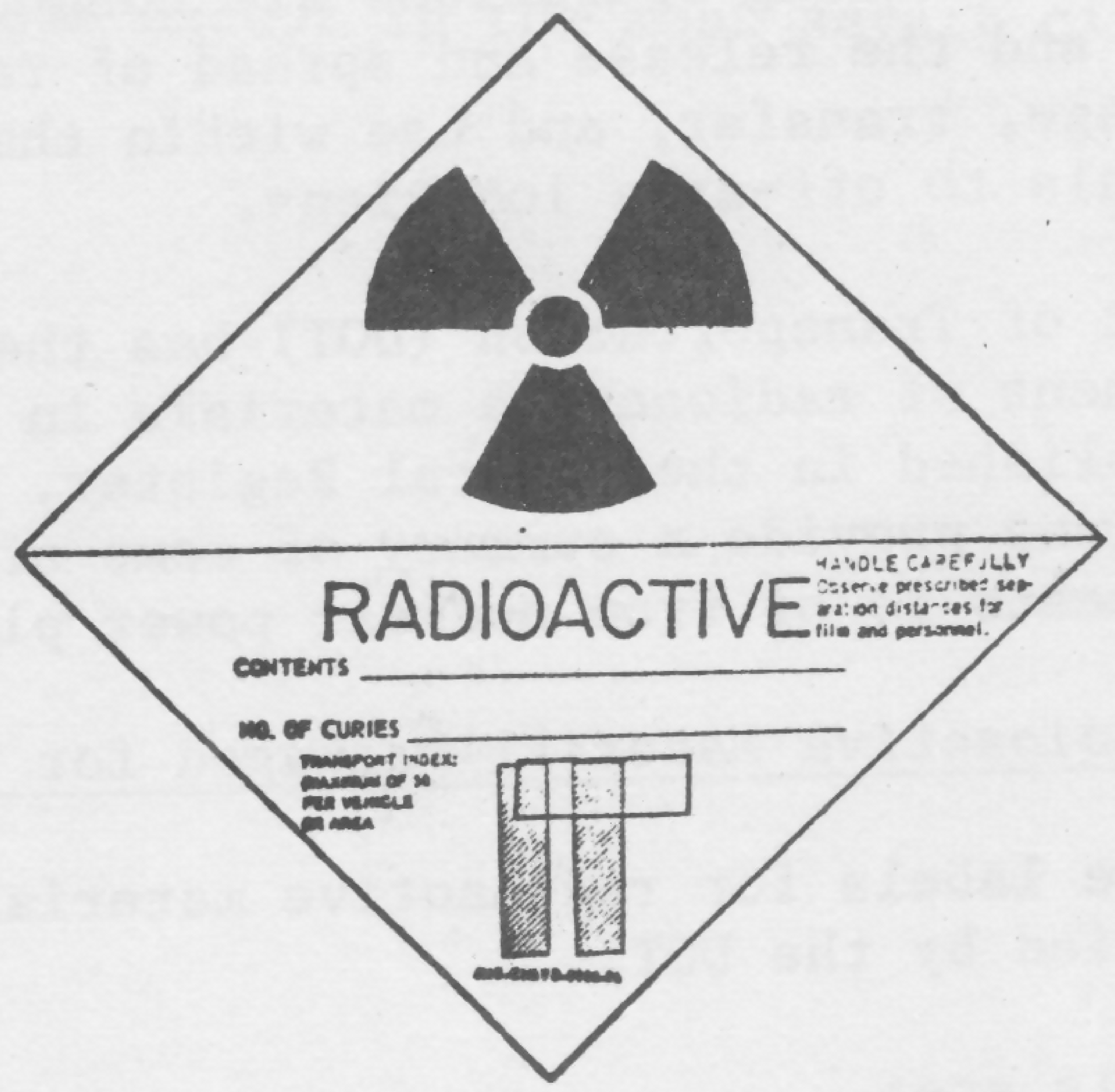
The labels are shown in the illustrations below:

a. Labels for packages of radioactive materials must be of diamond shape in colors specified in this section with each side at least 4 inches long. Printing must be in black inside a black line border measuring at least 3-1/2 inches on each side and as shown in this section.

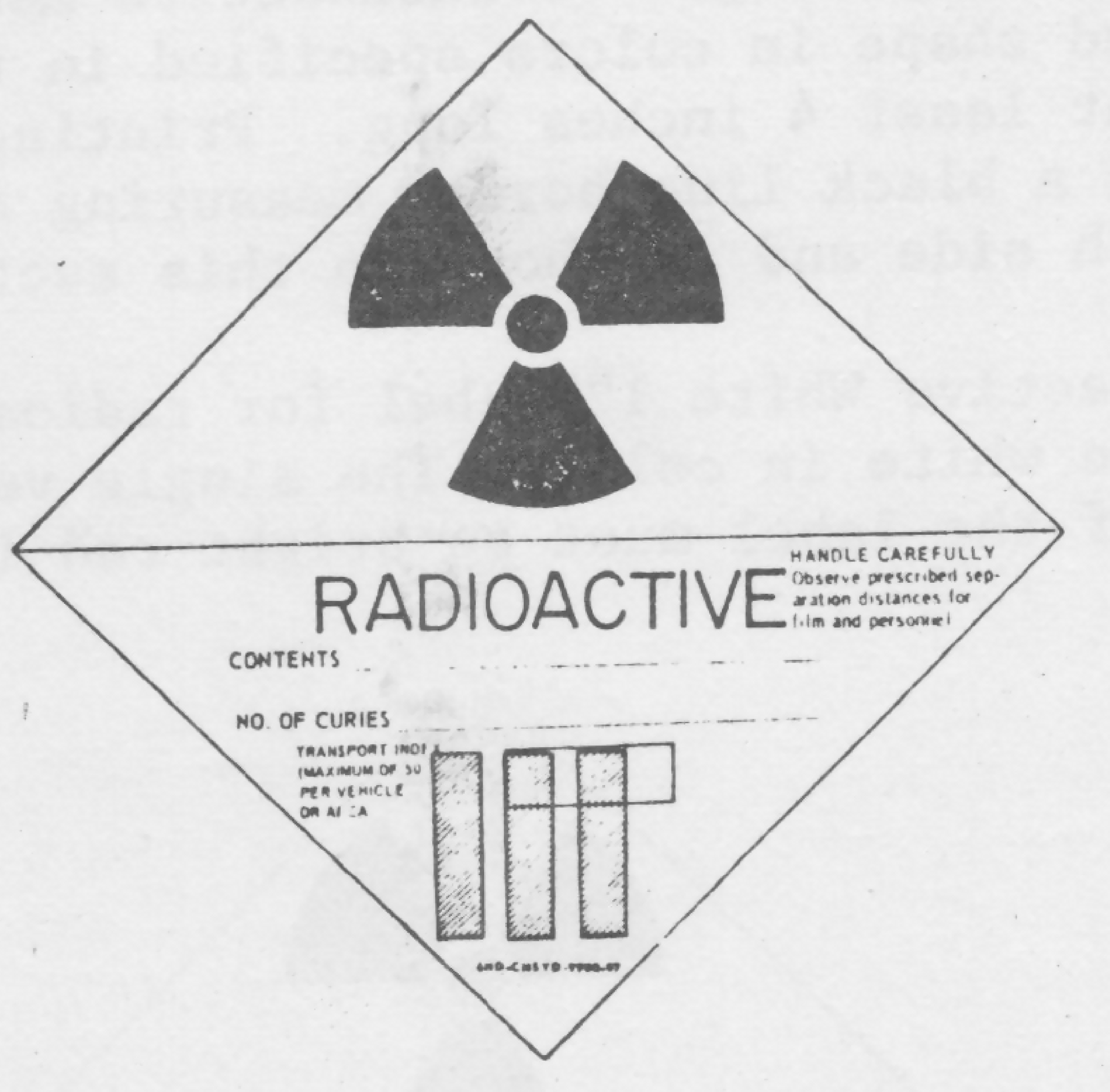
b. "Radioactive White I" label for radioactive materials. Label must be white in color. The single vertical bar on the lower half of the label must be bright red in color.



c. "Radioactive Yellow II" label for radioactive materials. The upper half of the label must be bright yellow and the bottom half must be white. The two vertical bars on the lower half of the label must be bright red in color.



d. "Radioactive Yellow III" label for radioactive materials. The upper half of the label must be bright yellow and the bottom half must be white. The three vertical bars on the lower half of the label must be bright red in color.



The following table lists certain types of radioactive materials which may be shipped from a nuclear plant and the types of labels required. Two labels must be affixed, one on each of two opposite sides, to each package.

1. Drummed waste or other packages of mixed fission products.

   Note: For other than mixed fission products the quantity of material allowed for exemption may vary.

   a. Less than 0.1 millicurie of material and with radiation levels less than 0.5 millirem per hour at external surface - exempt from labeling on outside of package (although the outside of the inner container must be labeled "Radioactive." If no inner container is present, label outside container).

   b. Greater than 0.1 millicurie of material but with radiation levels less than 0.5 millirem per hour at external surface, Radioactive White I.

   c. Radiation levels greater than 0.5 millirem but less than 10 millirem per hour at the external surface and less than 0.5 millirem per hour at three feet from surface, Radioactive Yellow II.

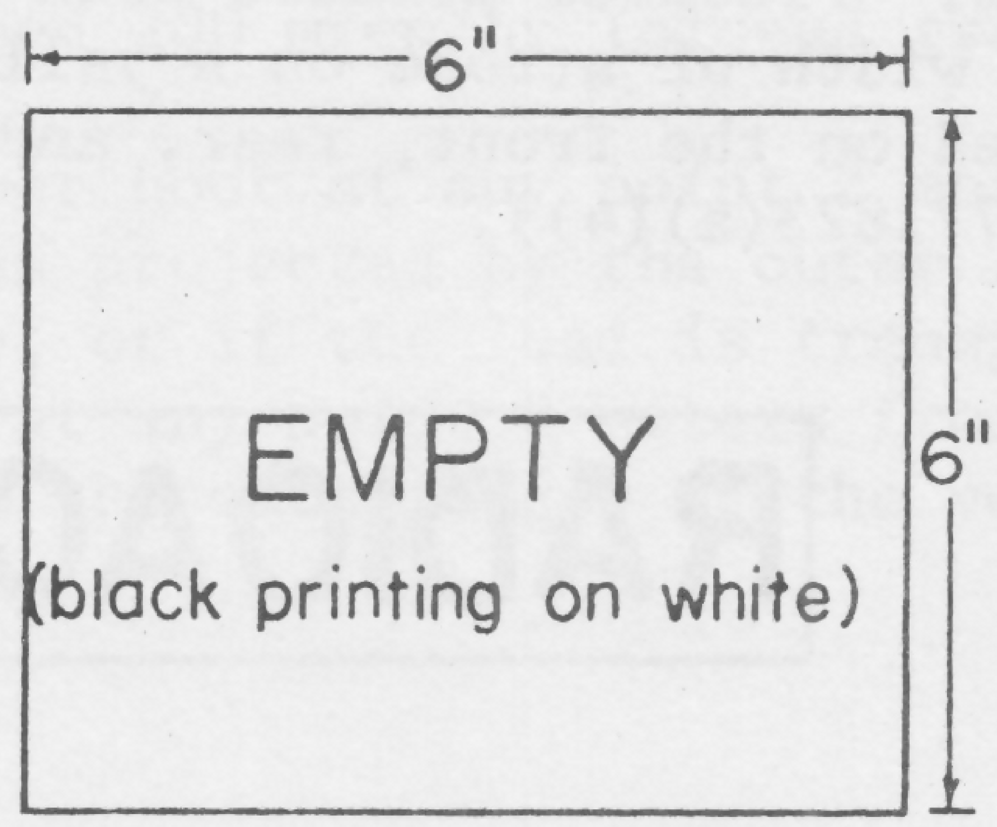
   d. Radiation levels greater than those in c. above, Radioactive Yellow III.

2. Spent fuel casks - loaded

   a. Radioactive Yellow III regardless of external radiation levels.

   b. All empty radioactive materials shipping containers must have "Empty" labels attached in such a way that the "Radioactive" shipping label is not visible. Removal of the "Radioactive" label is permitted. The requirements for attaching the "Empty" label are that the external surface must be free of removable radioactive contamination and the radiation level at the external surface must be less than 0.5 millirem per hour.

   The "Empty" label is shown in the illustration below. Letters must be at least one inch high.

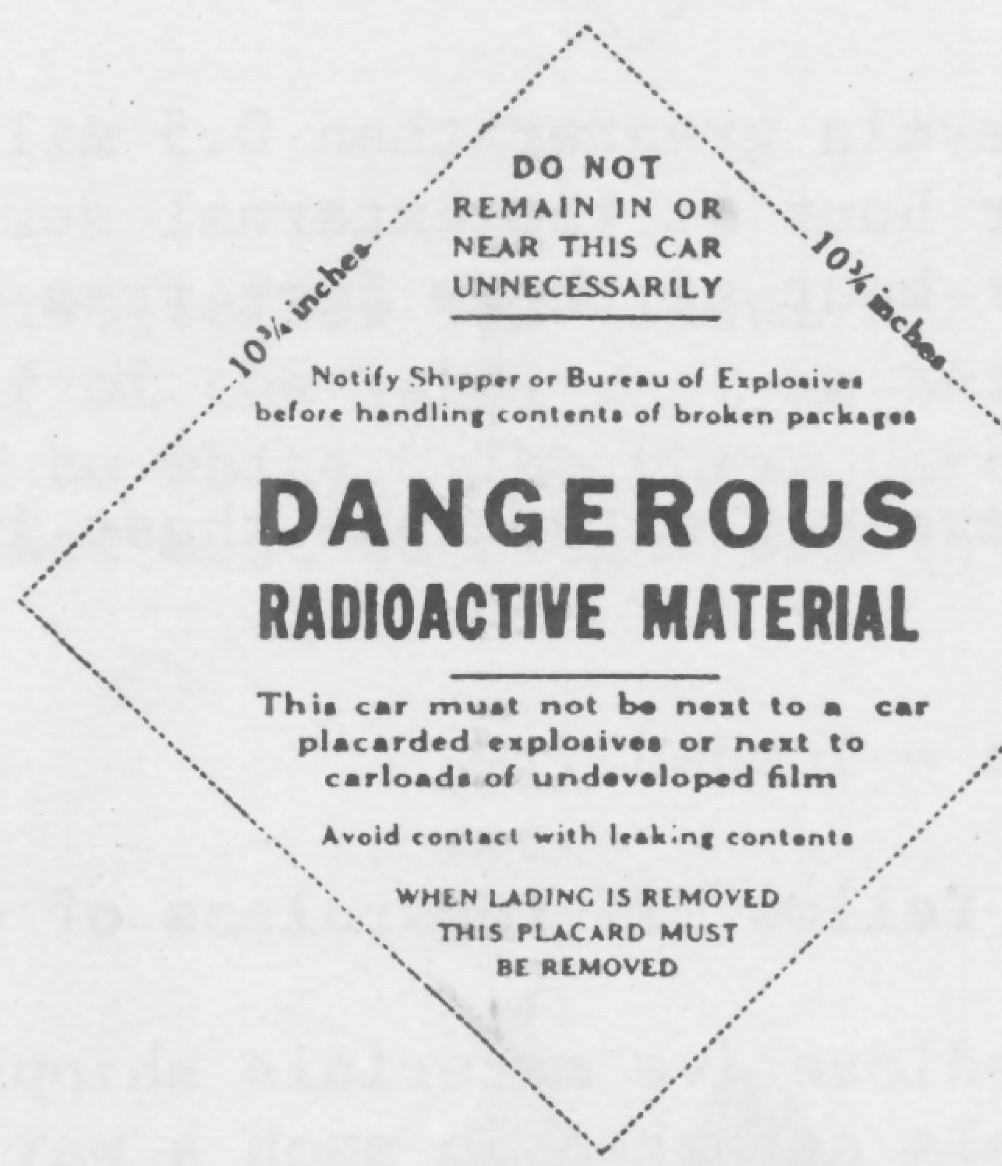


c. In addition to the above labels prescribed by the DOT, 10CFR20 requires a magenta (or purple) and yellow "Caution, Radioactive Material" label with the radiation symbol and sufficient information to permit handlers to know what precautions to take to protect themselves. This information will include appropriate radiation levels, kinds of material, estimated activity, date of estimated activity, mass enrichment, etc

B. Placarding of Vehicles Containing Radioactive Materials

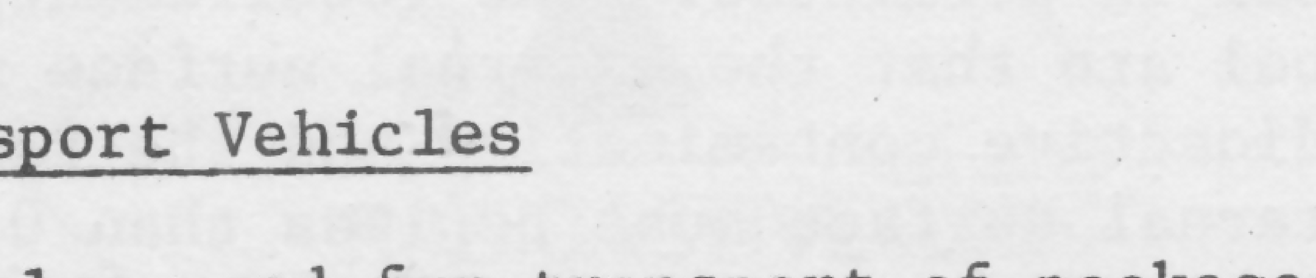
1. Rail Transport Vehicles

Unattended baggage or express cars containing packages bearing Radioactive Yellow III labels, and carload lots of low specific activity materials shipped via rail transport, must be placarded by the carrier. "Dangerous Radioactive Material" placards printed with red letters on white stock must be applied, one on each end and on each side. (49CFR 174.393(k), 174.541(b), 175.655(e) and 176.705.



2. Highway Transport Vehicles

Highway vehicles used for transport of packages bearing Radioactiv Yellow III labels must be placarded by the carrier, or by the shipp for sole-use vehicles containing full loads of low specific activit materials. Placards printed with black letters four inches high an 5/8 inch width of stroke on a yellow background as shown below must be applied on the front, rear, and on each side of the vehicle. (49CFR 177.823(a)(4)).



C. Radiation and Contamination Limits

Allowable radiation dose rates and contamination limits are listed under two different shipping conditions: (1) shipments made via commercial carriers (truck, train, aircraft, etc.) where other packages are also being transported; and (2) sole-use vehicles (except aircraft) which are assigned for the exclusive use of the consignor, loaded by the consignor, and unloaded by the consignee.

1. Commercial Carriers

a. The maximum dose rate at any point on the external surface of a package is 200 mrem/hr.

b. The transport index cannot exceed 10. (The transport index is defined as the highest radiation dose rate, in millirem per hour, at 3 feet from any accessible external surface of the package, i.e., 5 mrem/hr at 3 feet from a package would be a transport index of 5.)

c. There must be no "significant" removable radioactive surface contamination on the exterior of the package. Section 173.397 of 49CFR defines removable contamination as significant if the average amount which can be removed by wiping the external surface with an absorbent material exceeds 10 picocuries of beta-gamma per square centimeter (2,200 dpm per 100 cm^2) and one picocurie of alpha per square centimeter (220 dpm per 100 cm^2) for all contaminants except natural or depleted uranium and natural thorium.

d. Following unloading, the vehicle must be surveyed and cannot be reused if, at any accessible surface, the dose rate exceeds 0.5 mrem/hr and there is any "significant" removable contamination.

2. Sole-Use Vehicles

a. The maximum dose rate may not exceed 1000 mrem/hr at 3 feet from the external surface of a package (closed transport vehicle only). For open sole-use vehicles, the maximum is 200 mrem/hr at the external package surface.

b. The dose at any point on the external surface of the vehicle shall not exceed 200 mrem/hr (closed transport vehicle only).

c. Ten millirem per hour at any point 2 meters (6 feet) from the vertical planes projected by the outer lateral surface of the car or vehicle; or if the load is transported in an open transport vehicle, at any point 2 meters from the vertical planes projected from the outer edges of the vehicle.

d. The dose rate in any normally occupied position in the vehicle (any seats or sleeper cab) cannot exceed 2 mrem/hr.

e. There must be no significant removable radioactive surface contamination on the exterior of the package.

f. Following unloading, the vehicle must be surveyed. Sole-use closed vehicles may be reused provided the dose rate does not exceed 10 mrem/hr on interior surfaces or 2 mrem/hr at 3 feet from any interior surface. These vehicles must be stenciled with the words "FOR RADIOACTIVE MATERIALS USE ONLY."

D. Requirements for Handling, Storage, or Transfer of Radioactive Materials

1. Off-area shipments comply with regulations of the DOT and any other local regulations which may exist.

2. All transfers of radioactive materials to off-area locations are adequately shielded and contained. Temporary shielding or containment may be employed for radioactive materials while in transit on site. A health physics representative should be contacted to provide the necessary monitoring to ensure this.

3. All transfers, regardless of destination, are identified by appropriate labels and tags.

4. Applicable zoning and radiation control procedures are observed during all handling operations. A health physics representative should be contacted to monitor storage locations or handling operations to establish zoning or radiation protection requirements.

5. The TVA mail is not used for the transfer of radioactive materials.

6. A health physics representative routinely surveys radioactive sources for leaks and source storage areas for radiation and contamination hazards.

7. The supervisor of a source handling or transfer operation initiates request for an SWP when handling conditions warrant specific radiation or contamination control precautions.

Section XI

SAFE PRACTICES

Many recommended safe practices have already been discussed under requirements in specific sections of the handbook. This section summarizes some of the most important. These are rules which are necessary for everyone's protection and benefit when working with radioactive materials.

1. Do not enter a Radiation Area or Contamination Area without supervisory approval and without a knowledge of the magnitude of the hazard. A favorite shortcut between two areas may be temporarily barred by a rope bearing a Radiation Area sign. It is easy to step over; however, this can lead to an unnecessary radiation exposure.

2. Items (equipment, tools, etc.) being transferred from a Regulated Area, Contamination Area or Radiation Area to a Clean Area must be monitored and green tagged by a health physics representative.

3. Radiation area barriers and signs must not be moved or altered except by a health physics representative.

4. Eating, smoking, and drinking except from an approved fountain is prohibited in Contamination Areas.

5. Personnel and equipment may leave a Contamination Area only after monitoring shows them to be free from transferable contamination.

6. Transfer of radioactive liquid samples within the plant should be done in unbreakable "plastic bottles" to reduce the possibility of breakage and spread of contamination. These bottles should be properly tagged or labeled with a radiation tag as should any radioactive or contaminated item.

7. Work must not be performed in Radiation or Contamination Areas without TLD badges and pocket dosimeters.

8. Self-reading dosimeters when being worn should be observed at periodic intervals when working in radiation or high radiation areas.

9. Contamination area clothing must not be worn outside a Contamination or Regulated Area.

10. If masks, respirators, or special clothing are required, they must be worn. Personnel shall not deviate from these or any other conditions specified on an SWP.

11. When working in highly contaminated areas, personnel should periodically check the levels of contamination on their protective clothing. Clothing shall be changed when levels exceed 10 mrem/hr at one inch.

12. The required items of protective clothing shall be worn by all personnel when in Controlled Access Areas.

13. Protective clothing should be checked for good condition prior to putting on.

14. Damaged items of protective clothing shall be replaced immediately and the area around the break surveyed.

15. Hand and foot counters will be provided at various locations throughout the plant. They must be used by personnel leaving the particular area. A minimum of 5 seconds is required for the hand and foot counter to provide an accurate response. A little time spent here can be the most important in your day. Any contamination detected should be reported to the health physicist.

16. Personnel noting the malfunction of any radiation protection equipment or instruments shall report the condition to health physics.

17. All radiation sources, containers, etc., should be properly tagged even within Radiation Areas.

18. Any unusual operation or change in working conditions which might present a radiation hazard should be reported to the health physicist.

19. Report all near accidents or accidents. No accident should ever be concealed; although the results are minor, they might not be the next time. Something can be learned from every incident.

20. If injured in the Controlled Access Area, immediately leave the area and contact a health physics representative or the shift engineer and wait at the health physics station for assistance unless directed otherwise.

21. All open wounds must be properly protected prior to entry to Controlled Access Areas.

22. In cases of emergency, only division management shall release information concerning the situation to the public. Any questions shall be directed to appropriate management.

23. The following basic procedures should be followed in the case of minor incidents in the Controlled Access Areas such as low level radioactive material spills, unsuspected localized high radiation levels, small fires, etc.

    a. Confine cause of incident, if possible, when it can be determined that no serious radiation exposure will be involved. When in doubt about hazard, evacuate the area until a complete evaluation can be made.

    b. Clear area of all personnel and restrict entry into the area.

    c. Notify the shift engineer and health physics representative.

    d. Health physics personnel will normally survey the area, post and barricade, and advise on procedures to return the area to normal condition and decontaminate personnel as required.

    e. Work in the area will be resumed only after it is determined that it is safe to do so.

24. In certain special cases when the plant health physicist or his representative is not available and immediate action is required to make a rapid assessment of radiation and contamination conditions, qualified operating personnel, as designated by the plant superintendent, may make radiation surveys. However, radiation conditions must be clearly understood by the person concerned.

25. In decontamination work, every effort should be made to prevent the spread of contamination as follows:

    a. Working from the edges toward the center of a contaminated area or from the top toward the bottom.

    b. Prevent the tracking of contamination to other areas which implies a thorough knowledge of where the contamination lies and the use of proper protective clothing, especially shoe covers.

    c. An awareness that all equipment used in the cleanup and all run-off solutions are potentially contaminated and should be handled accordingly.

26. Dispose of all contaminated waste in properly marked containers supplied for this purpose. Do not throw clean waste into a container marked for contaminated waste; however, it is good practice to dispose of radiation signs, tags, etc., in the contaminated waste container. This avoids confusion which might result if a radiation tag is found in the ordinary trash.

27. Visitors and/or other persons not having radiation protection orientation will require an escort in the Controlled Access Area.

28. Personnel will at all times conduct themselves in a manner consistent with good industrial as well as radiological safety.

29. Personnel shall at all times attempt to minimize their radiation exposure consistent with performing assigned tasks.

30. When working in contamination stress, keep hands and other objects away from face or any other exposed parts of the body.

Appendix I

RADIATION MONITORING EQUIPMENT

Various types of equipment may be used to monitor radiation including the type, the dose rate, the accumulated dose, or the relative intensity. The instruments routinely used for health physics purposes may be divided into one of the three categories listed in this section. The following equipment is typical.

A. Portable Monitoring instruments

1. Cutie Pie CP-10

Radiation Detected: Gamma and Beta

Scales: 0-100 mrad/hr
0-1,000 mrad/hr
0-10,000 mrad/hr

Applications: This instrument is used to accurately measure dose rates due to gamma and beta radiations. This instrument may be provided in two forms:

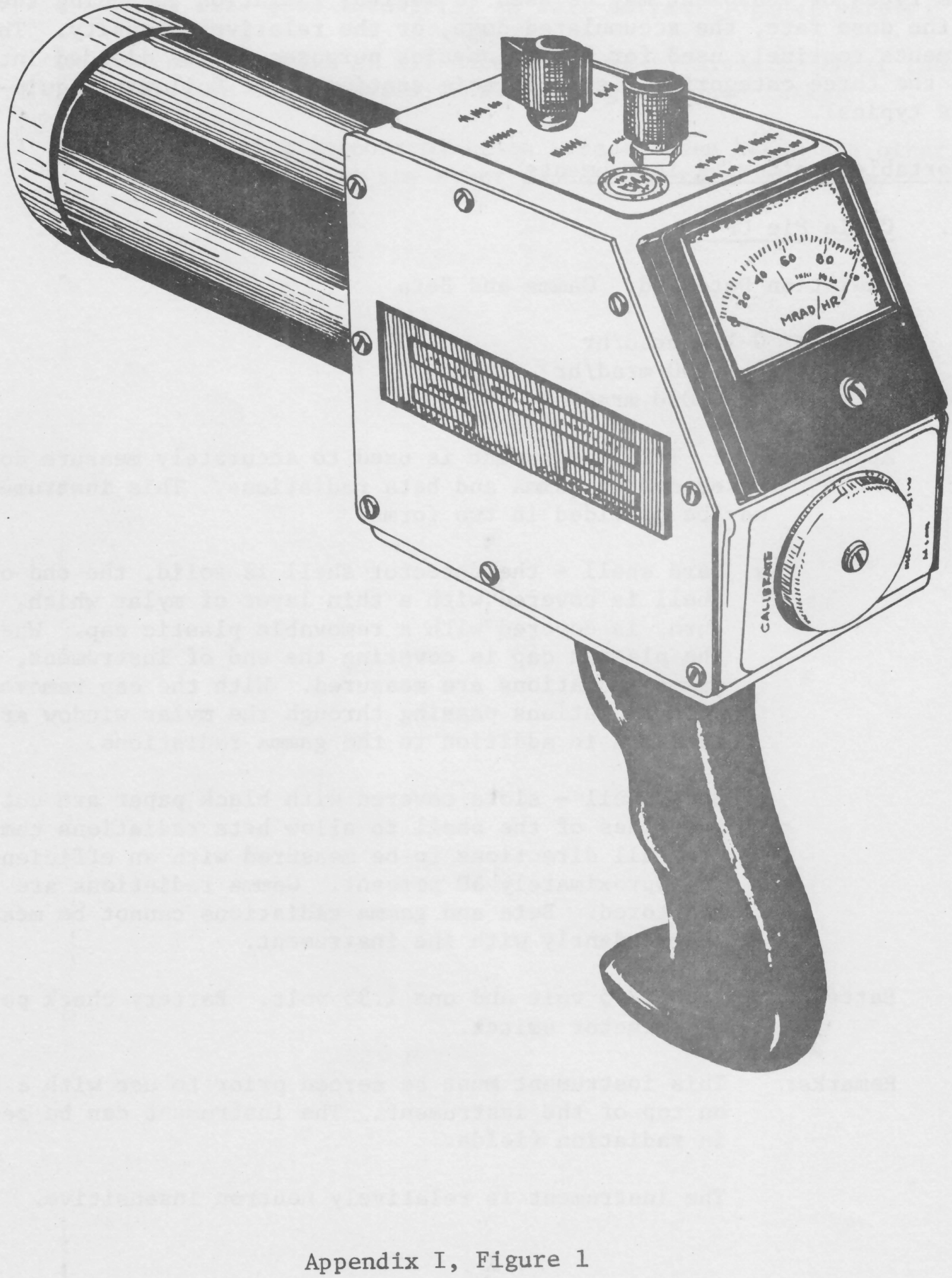
a. Hard shell - the detector shell is solid, the end of the shell is covered with a thin layer of mylar which, in turn, is covered with a removable plastic cap. When the plastic cap is covering the end of instrument, only gamma radiations are measured. With the cap removed, beta radiations passing through the mylar window are measured in addition to the gamma radiations.

b. Soft shell - slots covered with black paper are cut in the sides of the shell to allow beta radiations coming from all directions to be measured with an efficiency of approximately 50 percent. Gamma radiations are also monitored. Beta and gamma radiations cannot be measured independently with the instrument.

Batteries: Four 22.5 volt and one 1.35 volt. Battery check position on selector switch.

Remarks: This instrument must be zeroed prior to use with a knob on top of the instrument. The instrument can be zeroed in radiation fields.

The instrument is relatively neutron insensitive.



Appendix I, Figure 1

STANDARD CUTIE PIE

2. <u>Cutie Pie CP-2</u>

This instrument is the same as the CP-10 except for the scales which are as follows:

0-25 mrad/hr
0-250 mrad/hr
0-2,500 mrad/hr

3. <u>High Range Cutie Pie</u>

Radiation Detected: Gamma

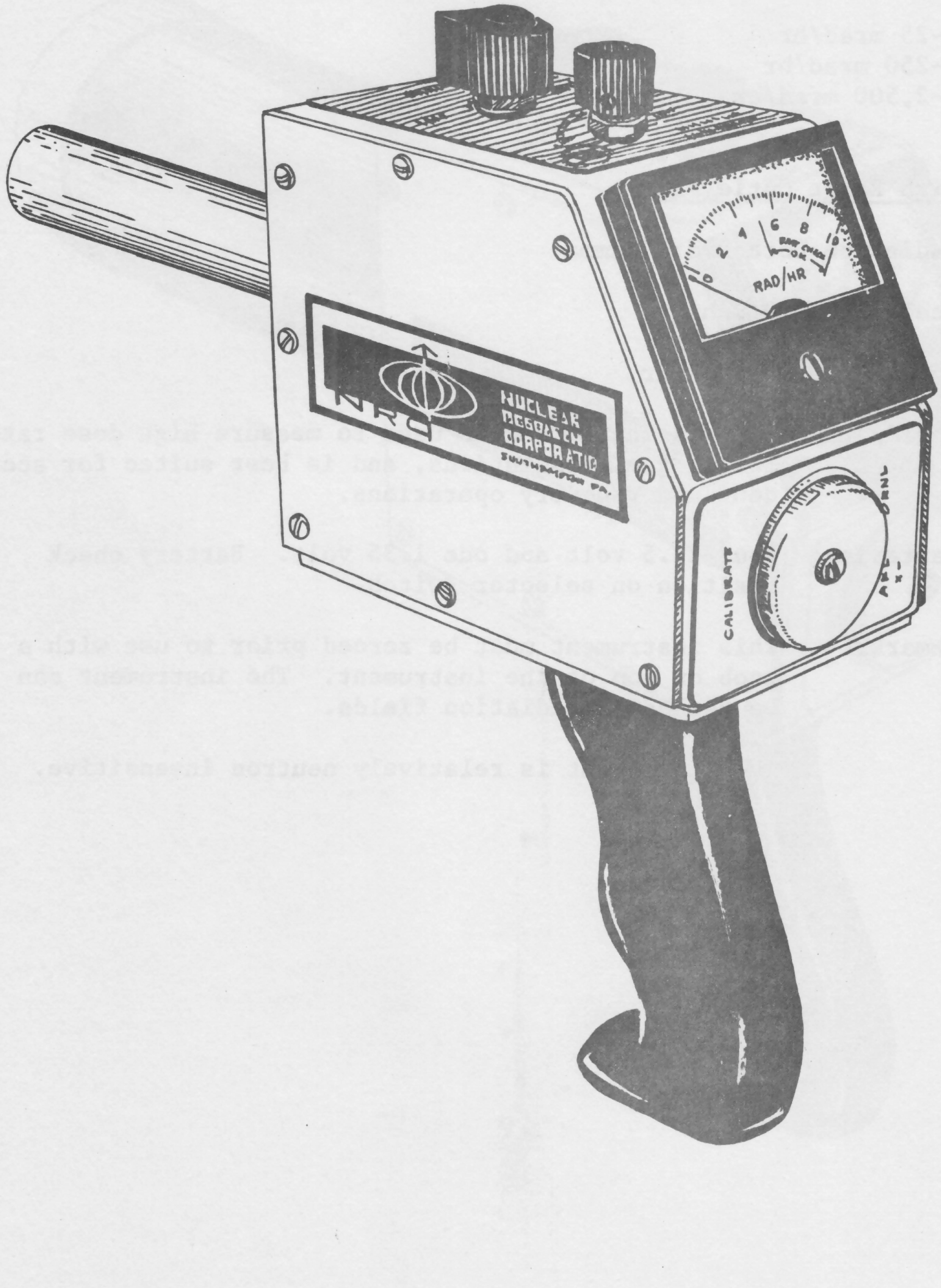
Scales: 0-10 R/hr
0-100 R/hr
0-1,000 R/hr

Applications: This instrument is used to measure high dose rates due to gamma radiations, and is best suited for accident and recovery operations.

Batteries: Four 22.5 volt and one 1.35 volt. Battery check position on selector switch.

Remarks: This instrument must be zeroed prior to use with a knob on top of the instrument. The instrument can be zeroed in radiation fields.

The instrument is relatively neutron insensitive.



Appendix I, Figure 2

HIGH RANGE CUTIE PIE

4. Extended Cutie Pie

Radiation Detected: Gamma and Beta

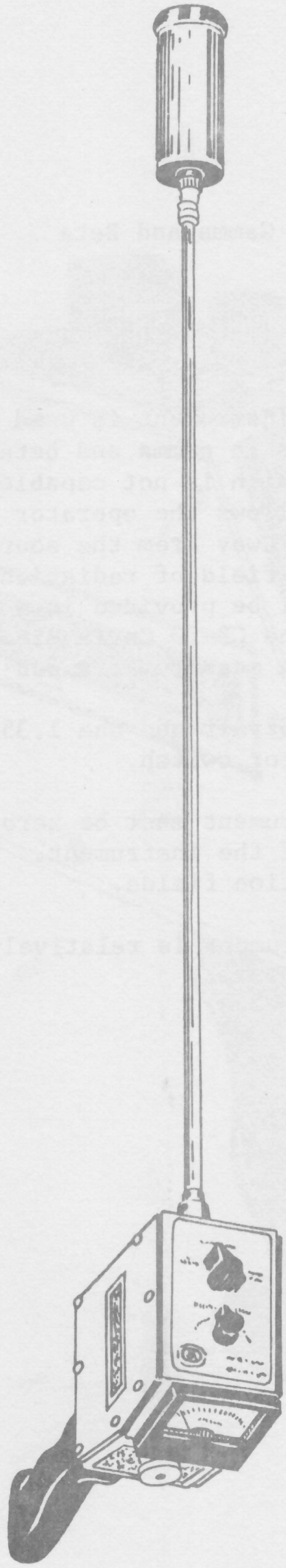
Scales: 0-1 rad/hr
0-10 rad/hr
0-100 rad/hr

Applications: This instrument is used to accurately measure dose rates due to gamma and beta radiations. The 3-foot probe, which is not capable of being extended or withdrawn, allows the operator to measure dose rates while standing away from the source of radiation and away from the field of radiation being measured. The instrument will be provided in a hard-shell version, identical to the CP-10 Cutie Pie, in which gamma and gamma-plus-beta measurements can be made.

Batteries: Four 22.5 volt and one 1.35 volt. Battery check position on selector switch.

Remarks: The instrument must be zeroed prior to use with a knob on top of the instrument. The instrument can be zeroed in radiation fields.

The instrument is relatively neutron insensitive.



Appendix I, Figure 3

EXTENDED CUTIE PIE

5. <u>Neutron Survey Meter</u>

1. Radiation Detected: 0.025 eV (thermal) to 10 MeV neutrons

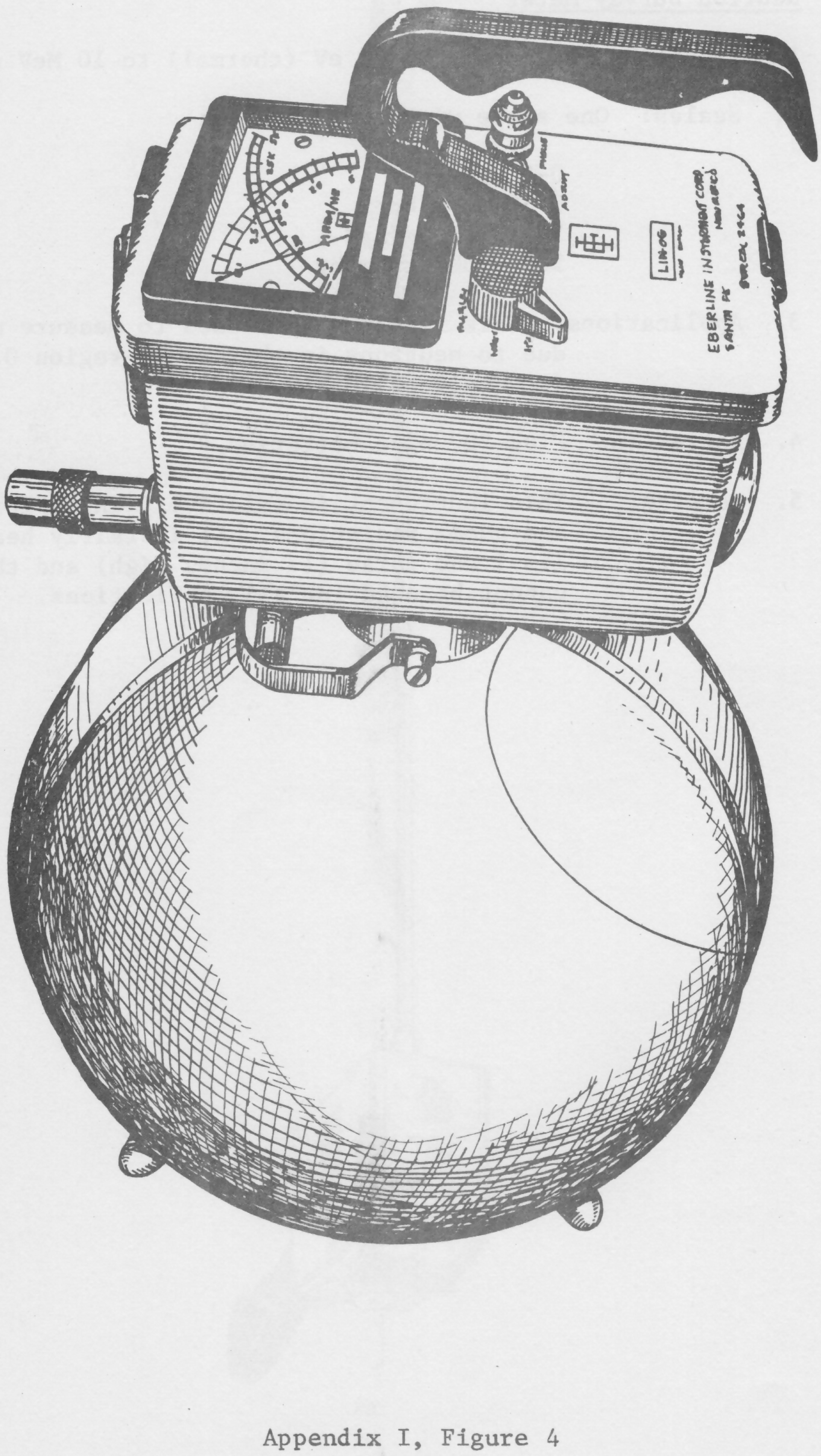
2. Scales: One scale with four decades:

   0-5 mrem/hr
   5-50 mrem/hr
   50-500 mrem/hr
   500-5,000 mrem/hr

3. Applications: This instrument is used to measure dose rates due to neutrons in the energy region 0.025 eV (thermal) to 10 MeV.

4. Batteries: Five "D" size batteries.

5. Remarks: This instrument is relatively insensitive to beta and gamma radiations. It is fairly heavy (19.5 lbs.) and large (17 inches high) and therefore cannot be used for all applications.



Appendix I, Figure 4

NEUTRON SURVEY METER

6. G-M Survey Meter

Radiation Detected: Gamma and Beta

Scales: 0-250 cpm
0-2,500 cpm
0-25,000 cpm
0-250,000 cpm

Applications: This instrument is used to detect gamma and beta radiations. Readout is provided by means of a rate meter and an audible pulse is optional. This type instrument is used to detect the presence of radiation and should never be used to set a dose rate in mR/hr or mrad/hr.

Batteries: Two 1.5 volt "D" cell batteries. Battery check position on selector switch.

Remarks: Two types of detectors are used with this instrument. A sliding shield on one detector can be used to discriminate between beta and gamma radiation. The beta radiation will not penetrate the metal shield. An end window detection is also available. It is the detector shown in figure 5. The instrument will not saturate (show zero or low count rate on rate meter) at dose rates up to 100 R/hr. This instrument is relatively insensitive to neutrons.

Appendix I, Figure 5

G-M SURVEY METER

7. Teletector

Radiation Detected: Gamma and Beta

Scales:
0-2 mR/hr
0-50 mR/hr
0-2 R/hr
0-50 R/hr
0-1,000 R/hr

Applications: This instrument has a telescoping probe that extends 13 feet to allow measurements to be taken with the operator standing away from the source of radiation and away from the field of radiation being measured. It is used to:

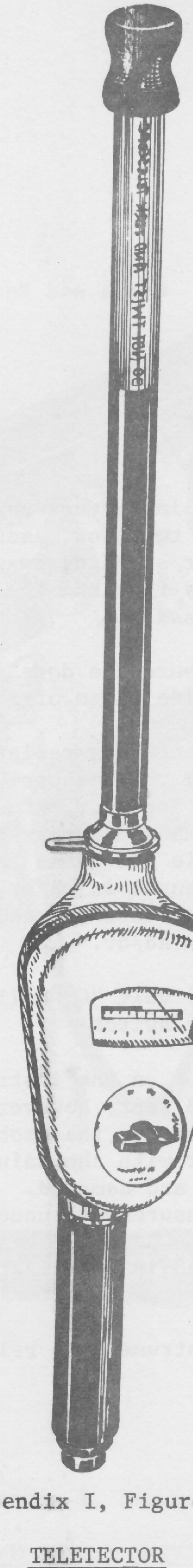
a. Measure the dose rate due to gamma radiations over a wide range of intensities.

b. Detect beta radiations by removing the rubber tip from the detector. When the tip is removed from the detector, it should be remembered that both gamma and beta radiations are being detected and, while the gamma radiations are being accurately measured in mR/hr, the beta radiations are only being detected and the results cannot be expressed in mrad/hr.

Batteries: Four 1.5 volt "C" cells. Battery check position on selector switch.

Remarks: The probe on the instrument can be extended any length up to 13 feet; however, great care must be exercised in retracting the probe as the wire connecting the detector with the main body of the instrument can be crimped and damaged. This instrument can be used to make measurements under water; however, when this is done, the detector head and telescoping probe must be contained in the plastic sheath provided for this purpose.

This instrument is relatively neutron insensitive.



Appendix I, Figure 6

TELETECTOR

8. <u>Low Energy Survey Meter</u>

Radiation Detected: Gamma and Beta

Scales:
0-3 mrad/hr
0-10 mrad/hr
0-30 mrad/hr
0-100 mrad/hr
0-300 mrad/hr

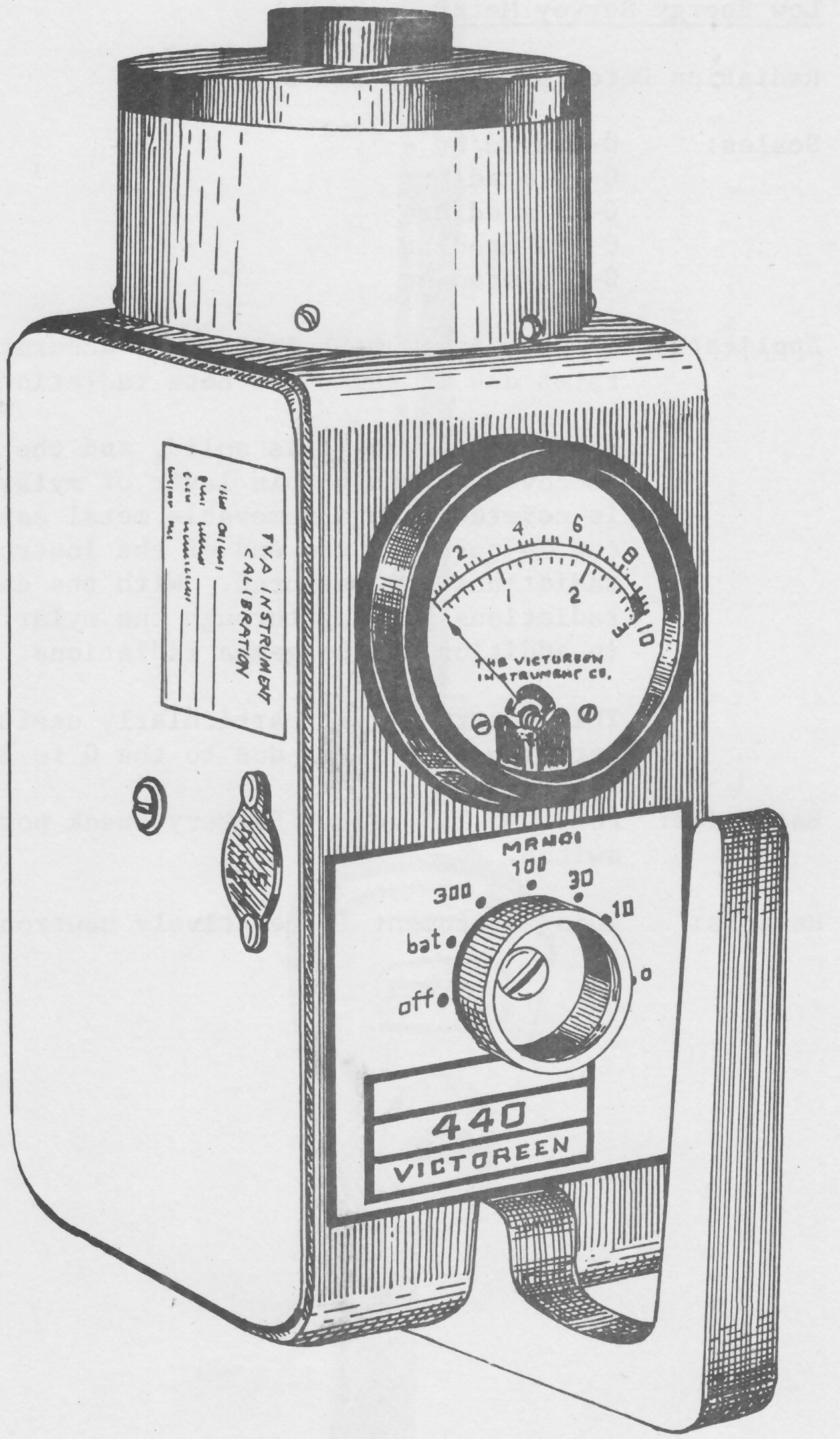
Applications: This instrument is used to accurately measure dose rates due to gamma and beta radiations.

The detector shell is solid, and the end of the shell is covered with a thin layer of mylar which, in turn, is covered with a removable metal cap. When the metal cap is covering the end of the instrument, only gamma radiations are measured. With the cap removed, beta radiations passing through the mylar window are measured in addition to the gamma radiations.

This instrument is particularly useful in measuring very low dose rates due to the 0 to 3 mrad/hr scale.

Batteries: Four "D" 1.5 volt. Battery check position on selector switch.

Remarks: This instrument is relatively neutron insensitive.



Appendix I, Figure 7

<u>LOW ENERGY SURVEY METER</u>

B. Personnel Dosimetry

1. TLD Badge

Radiation Detected: Gamma, Beta, Fast Neutron

Applications: Routine monitoring of integrated dose.

Remarks: Always worn while in plant; exchanged and processed periodically.

2. Criticality Dosimeter

Radiation Detected: Neutron

Applications: Measurement of total absorbed dose during criticality accident.

Remarks: Criticality components processed only after accident.

3. Direct Reading Pocket Chamber

Radiation Detected: Gamma

Applications: Measurement of absorbed dose during specific operation when periodic assessment of absorbed dose is required.

Remarks: Charger required for zeroing; range: 0-200 mR.

4. Accident Dosimetry

Radiation Detected: Gamma

Applications: Measurement of absorbed dose during specific operation when periodic assessment of absorbed dose is required.

Remarks: Charger required for zeroing; range: 0-50 R.

C. Laboratory Counting Systems

1. G-M Counter

Radiation Detected: Gamma and Beta

Applications: Measuring beta and gamma contamination levels on paper smears and planchets.

Remarks: Relatively low counting efficiency; easily decontaminated.

2. Proportional Counter

Radiation Detected: Gamma, Beta, and Alpha

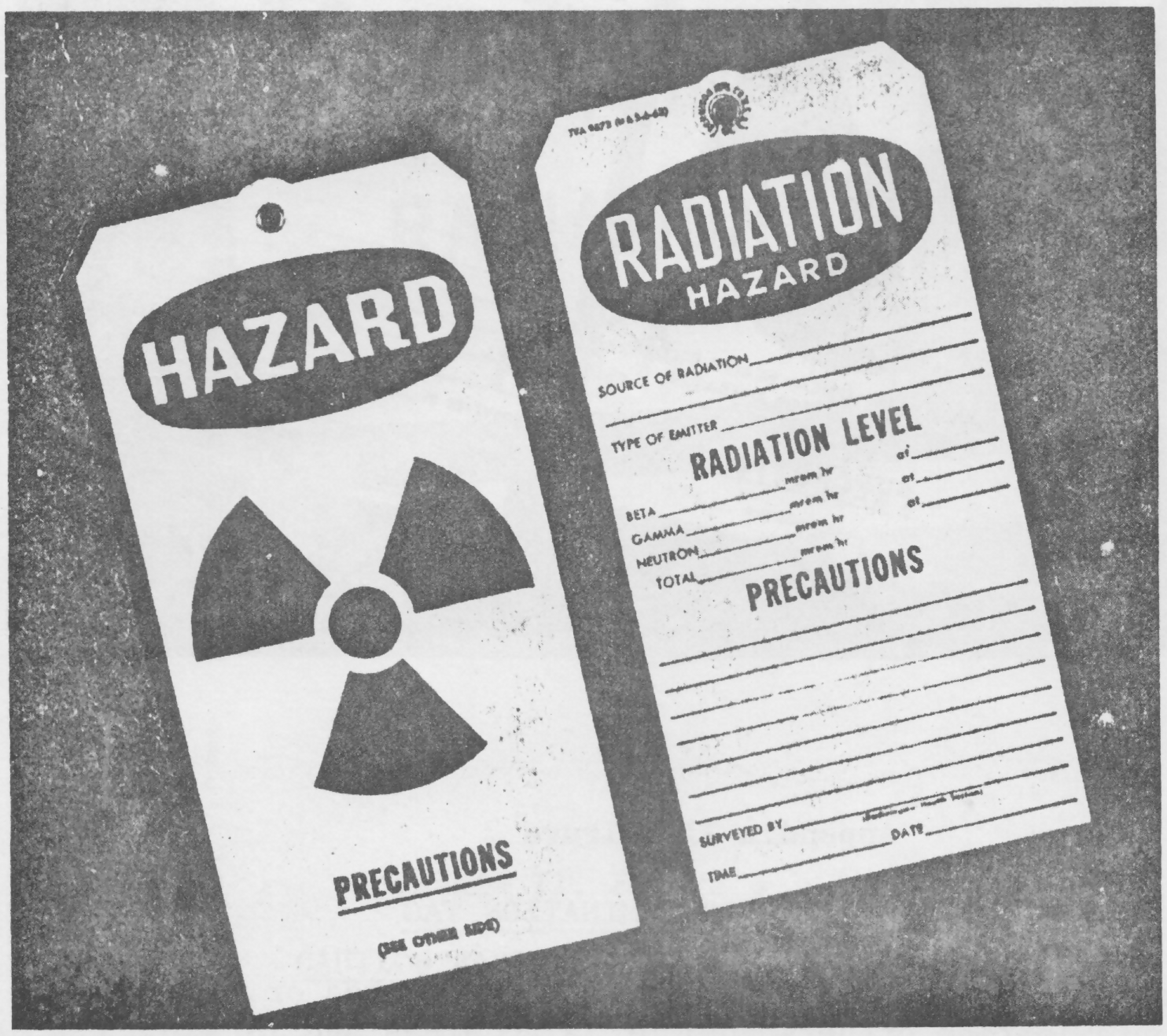
Applications: Measuring gamma, beta, and alpha contamination levels on paper smears and planchets.

Remarks: Relatively high counting efficiency; sample is placed in the counting chamber and, if the chamber becomes contaminated, it must be disassembled for cleaning; can differentiate between alpha and beta-gamma radiation.

Appendix II

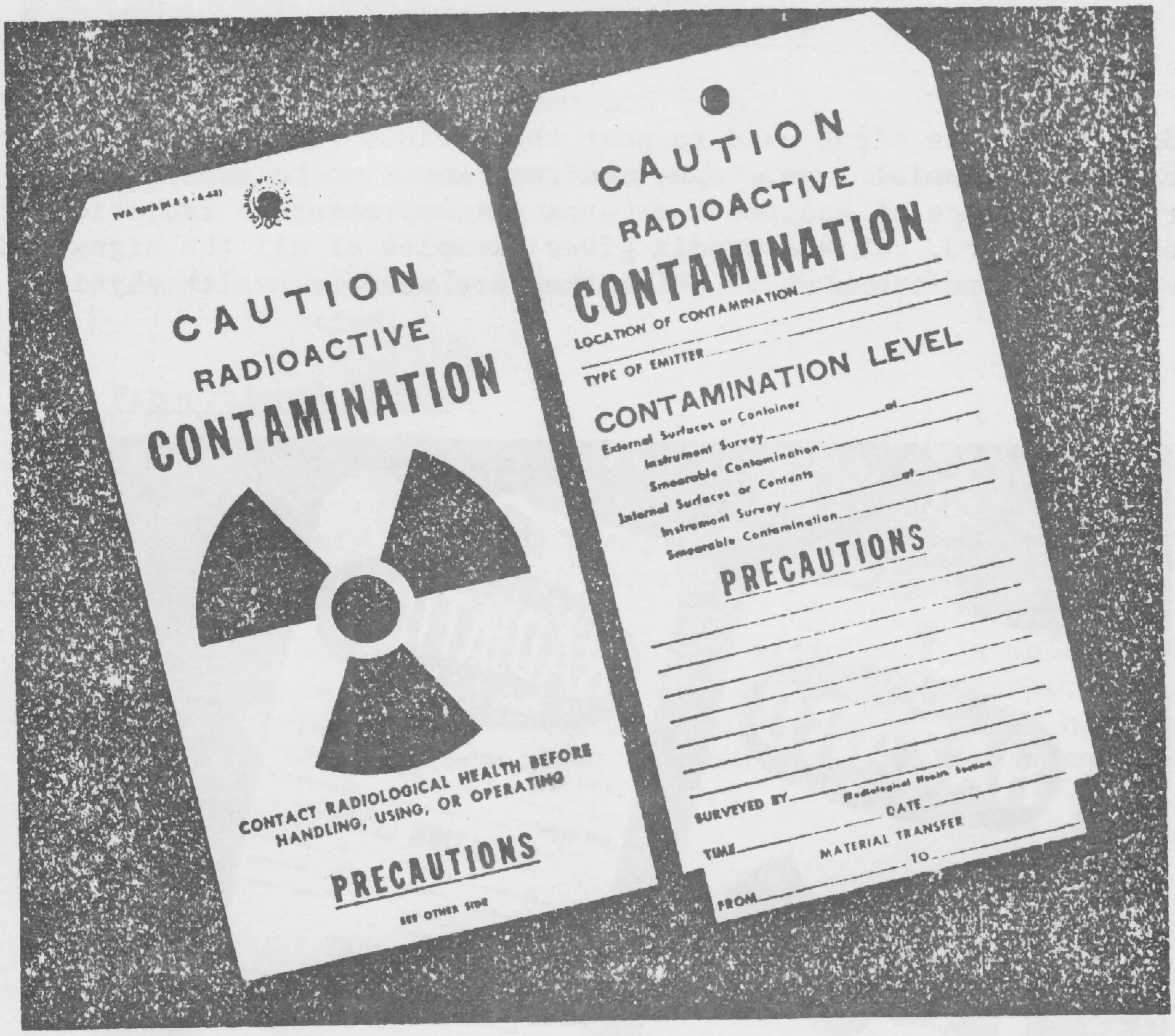
SIGNS, TAGS, LABELS

In addition to the signs used to post the various radiation and contamination areas, special tags, tape, and rope may also be used to identify a particular piece of equipment or area which presents a radiation or contamination hazard. This appendix gives examples of all the signs and tags used and the conditions under which they are used by health physics.



Appendix II, Figure 1

RADIATION HAZARD TAG



Appendix II, Figure 2

RADIOACTIVE CONTAMINATION TAG

The radioactive contamination tag identifies an area or object which may involve contamination of personnel or large areas and in which one or more of the following conditions may apply.

Surface Contamination	α (direct reading) >300 dpm/100 cm^2
	α (transferable) >30 dpm/100 cm^2
	β,γ (direct reading) >0.25 mrad/hr
	β,γ (transferable) >1,000 dpm/100 cm
Airborne Contamination	$>(MPC)_a$ for 40-hour week

Appendix II, Figure 3

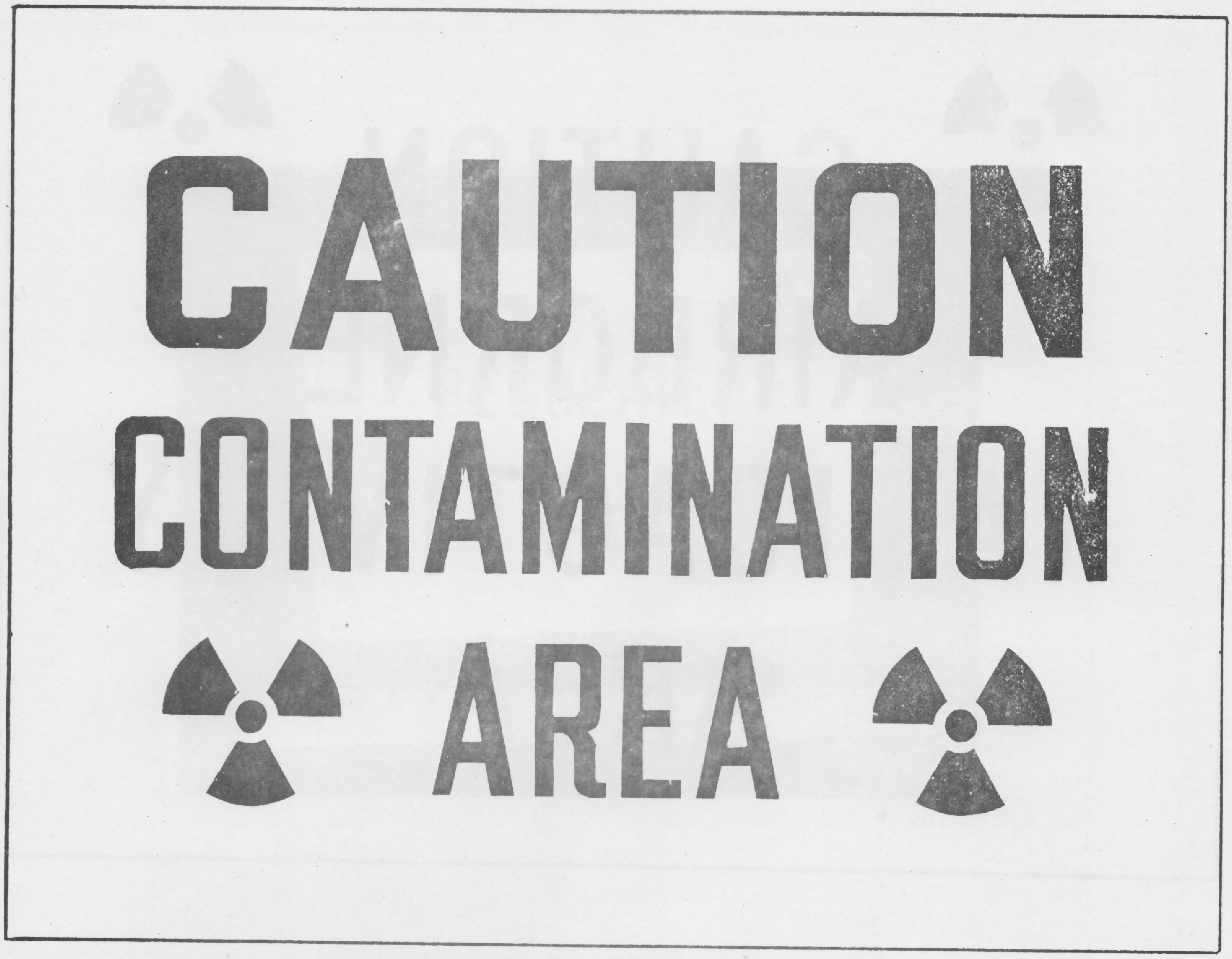
CAUTION RADIATION AREA SIGN

A permanent sign used to identify an area where the radiation level is greater than 5 mrem/hr but less than 100 mrem/hr.

Appendix II, Figure 4

<u>DANGER HIGH RADIATION AREA</u>

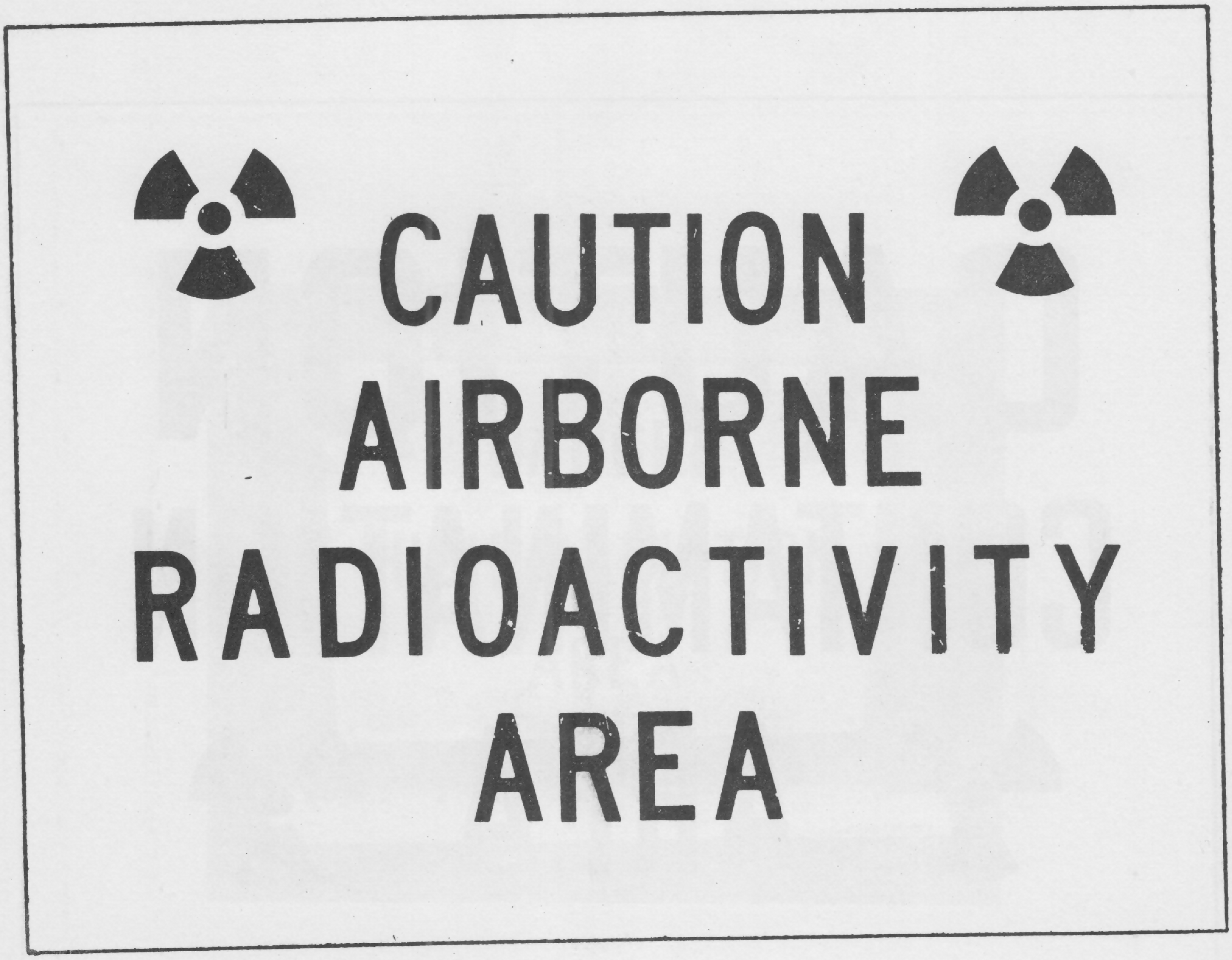
A permanent sign used to identify an area where the radiation level is 100 mrem/hr or greater.



Appendix II, Figure 5

CONTAMINATION AREA SIGN

A permanent sign is used to identify a permanent contamination area.



Appendix II, Figure 6

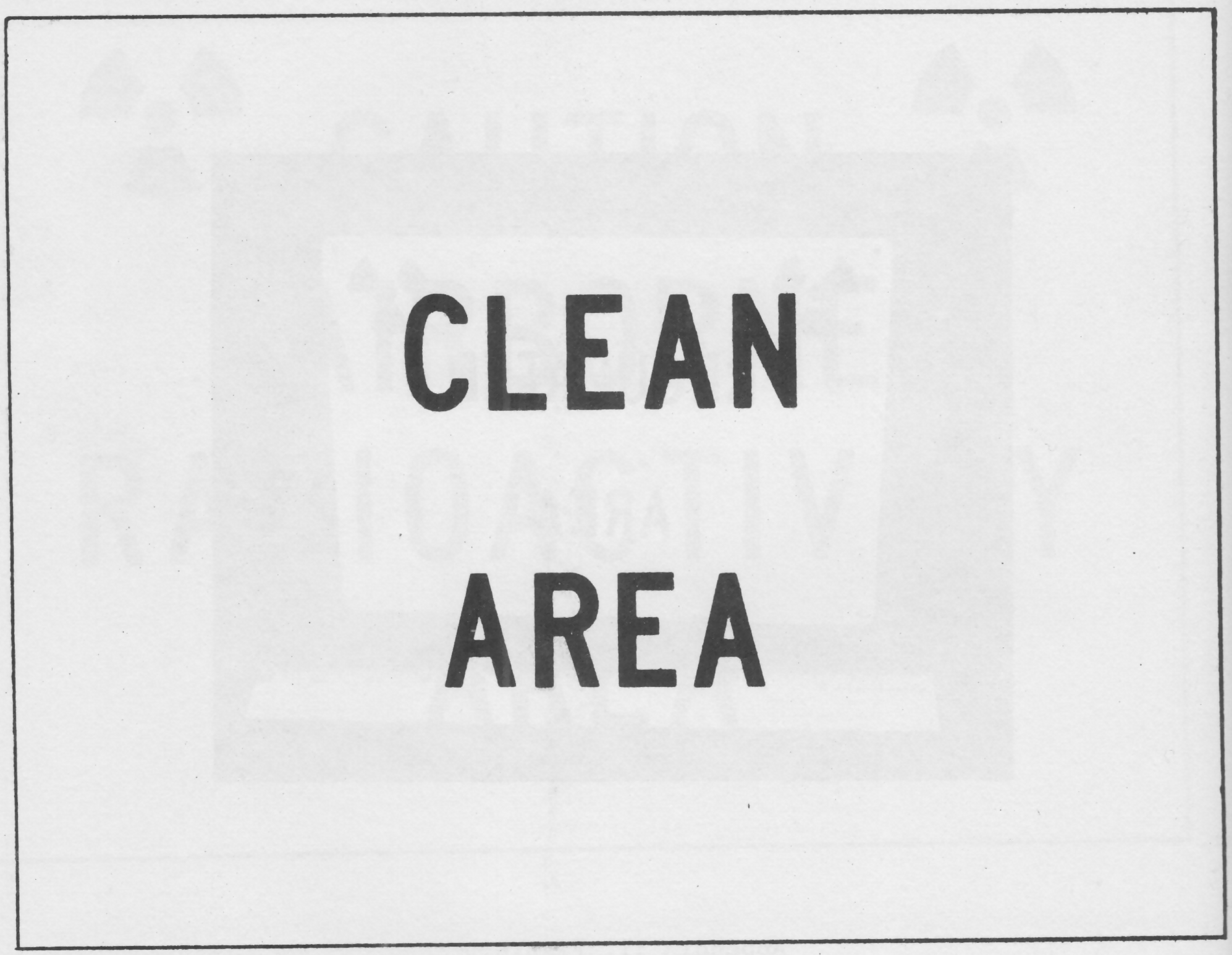
CAUTION AIRBORNE RADIOACTIVITY AREA

A sign used to define an area where the airborne radioactive material concentration exceeds the criteria in Section VIII, Table 10.

Appendix II, Figure 7

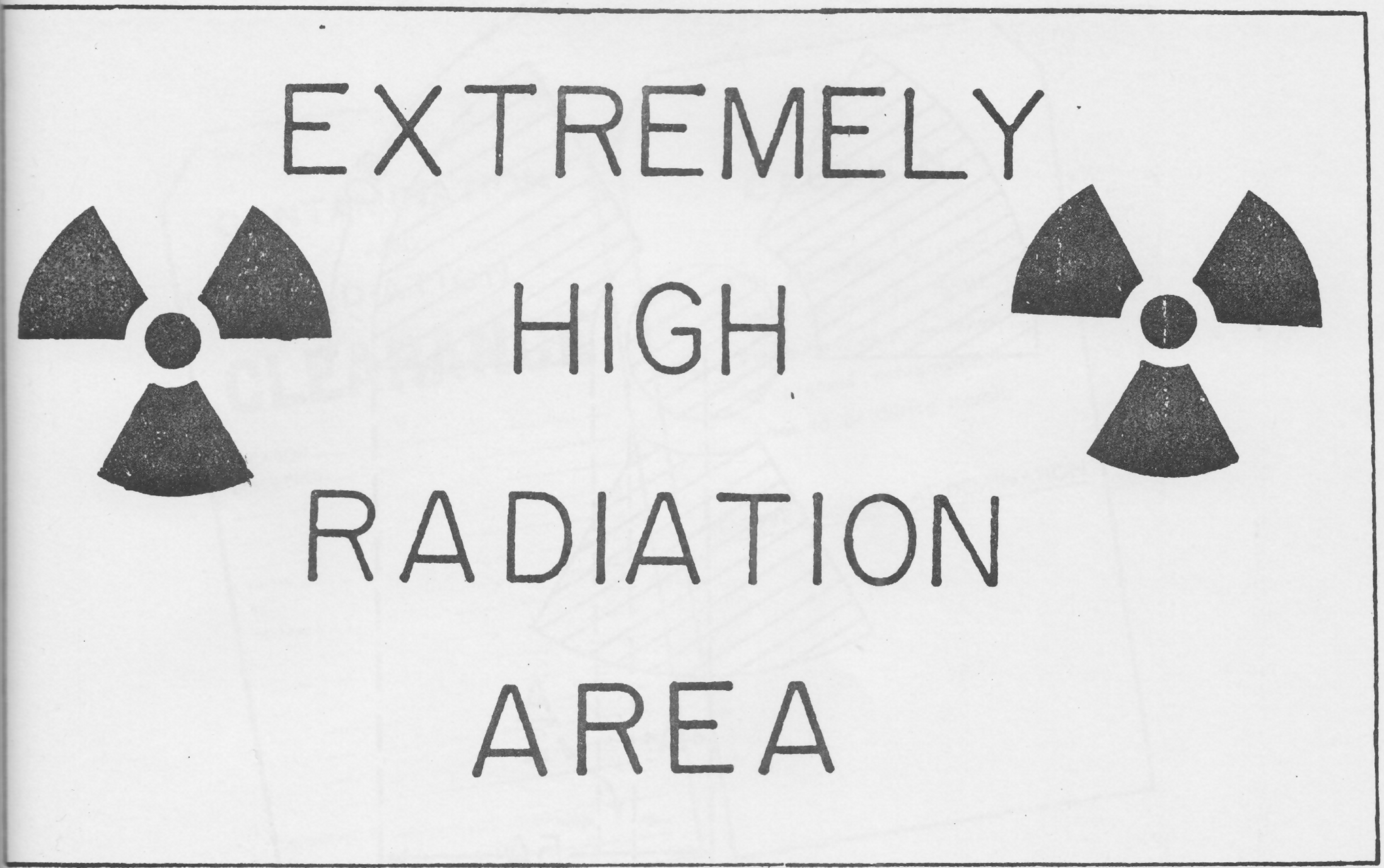
REGULATED AREA SIGN

A permanent sign used to identify a regulated area.



Appendix II, Figure 8

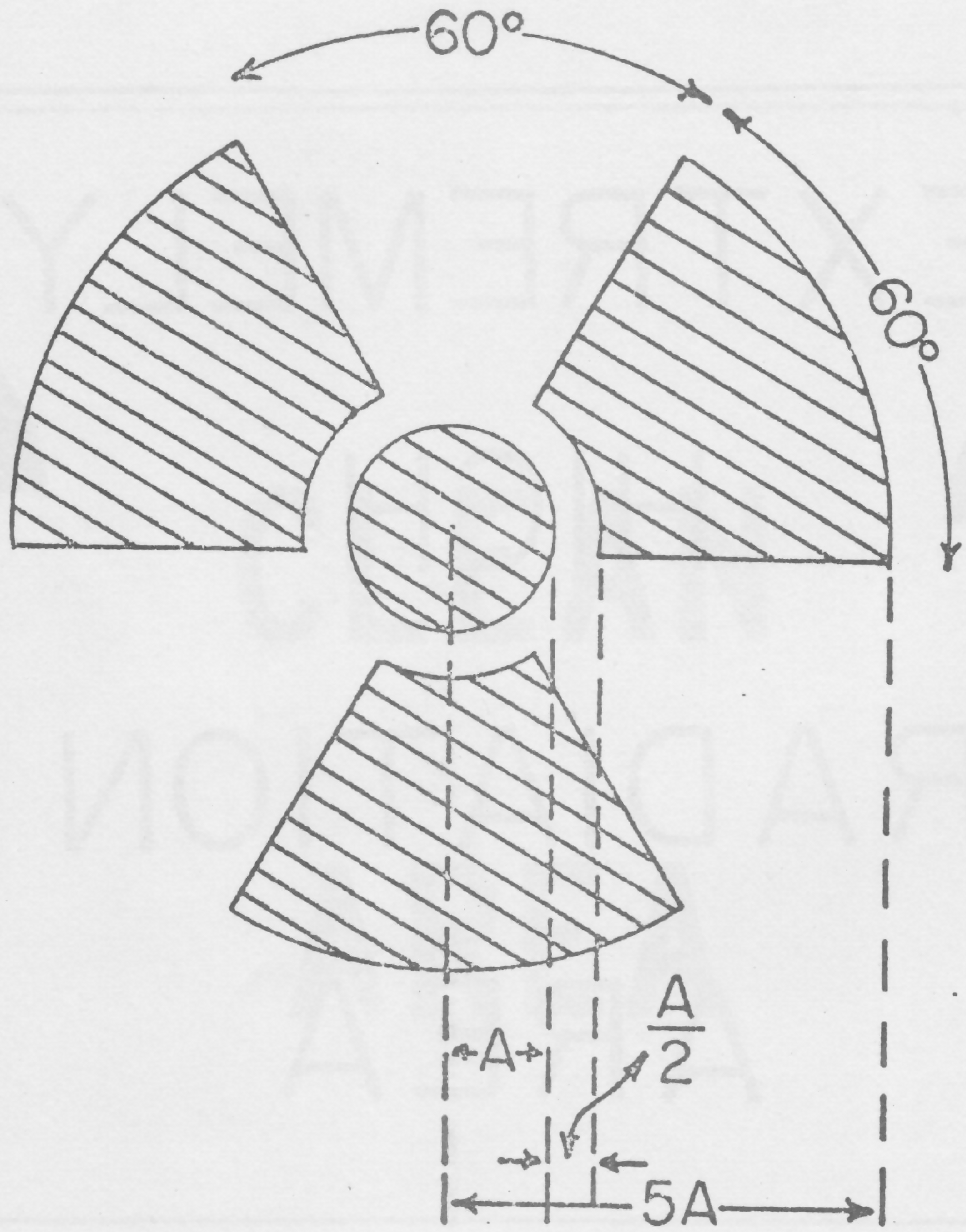
CLEAN AREA SIGN



Appendix II, Figure 9

EXTREMELY HIGH RADIATION AREA SIGN

To be posted only where the radiation exposure dose rate to the whole body is $\geq$10 rem/hour. Special locking devices and entrance procedures may be used as appropriate.



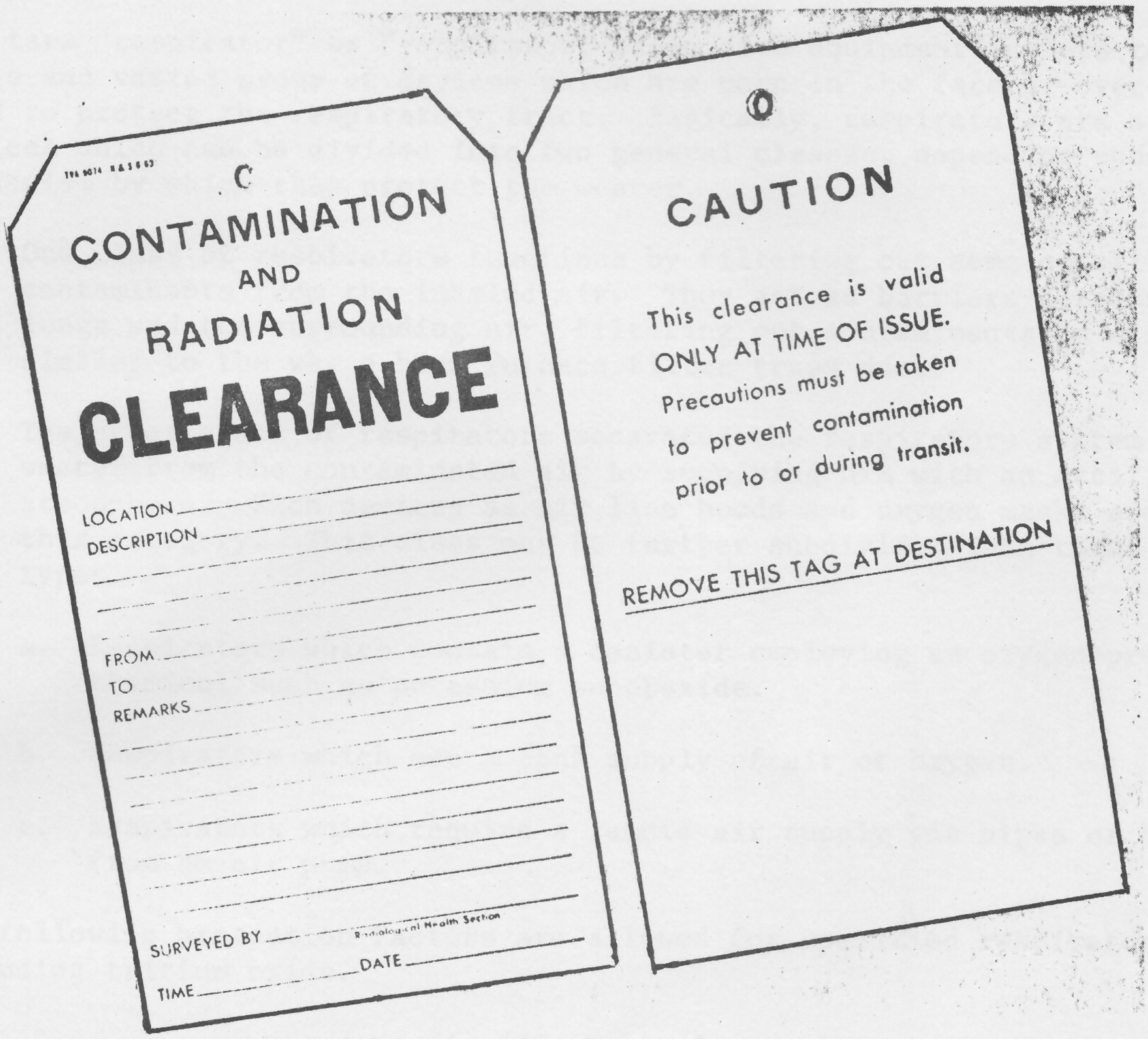
Appendix II, Figure 9

STANDARD RADIATION SYMBOL

The standard radiation symbol adopted March 1, 1960, by the American Standards Association signifies the presence of radiation or radioactive materials.

A. Cross-hatched area is to be magneta or purple.

B. Background is to be yellow.



Appendix II, Figure 10

CONTAMINATION AND RADIATION CLEARANCE TAG

A clearance tag is attached to an item which has been surveyed and found free of detectable radiation or excessive contamination. The object may be released as a clean item.

Appendix III

RESPIRATORY PROTECTIVE EQUIPMENT

Discussion

The term "respirator" or "respiratory protective equipment" refers to a large and varied group of devices which are worn on the face or over the head to protect the respiratory tract. Basically, respirators are simple devices which can be divided into two general classes, depending upon the mechanism by which they protect the wearer.

1. One class of respirators functions by filtering out some or all of the contaminants from the inhaled air. They act as barriers between the lungs and the surrounding air, filtering out contaminants in a manner similar to the way a home furnace filter traps dust.

2. The other class of respirators separates the respiratory system of the wearer from the contaminated air by supplying him with an artificial atmosphere. Such devices as air line hoods and oxygen masks are in this category. This class may be further subdivided into three general types.

   a. Respirators which contain a canister employing an oxygen-producing chemical such as potassium superoxide.

   b. Respirators which use a tank supply of air or oxygen.

   c. Respirators which require a remote air supply via pipes or hose from an air pump.

The following protection factors are allowed for specified respirators, excluding tritium oxide.

Appendix III, Table 1

PROTECTION FACTOR GUIDELINES FOR RESPIRATORS

Description	Protection Factor
Full face respirator (filter)	50
Supplied air breathing apparatus (air line) pressure demand type	2,000
Supplied air breathing apparatus (self-contained) pressure demand type	10,000

RESPIRATORY REQUIREMENTS FOR AIRBORNE CONTAMINANTS

Concentration Levels (Microcuries/cc Air) Alpha	Beta-Gamma*	Action
$<7 \times 10^{-11}$	$<3 \times 10^{-9}$	Masks not required unless contamination is identified and is above MPC for a 40-hour week.
7×10^{-11} to 3.5×10^{-9}	3×10^{-9} to 1.5×10^{-7}	Full-face mask required or complete evacuation of personnel from area.
$>3.5 \times 10^{-9}$	$>1.5 \times 10^{-7}$**	Positive air supply (hose line, air tanks) or complete evacuation of personnel from area. Working times must be used where MPC is exceeded by more than 1,000.

*Only supplied air and SCBA provide protection for Halogens.
**In this concentration range, the immersion dose rate may be significant.

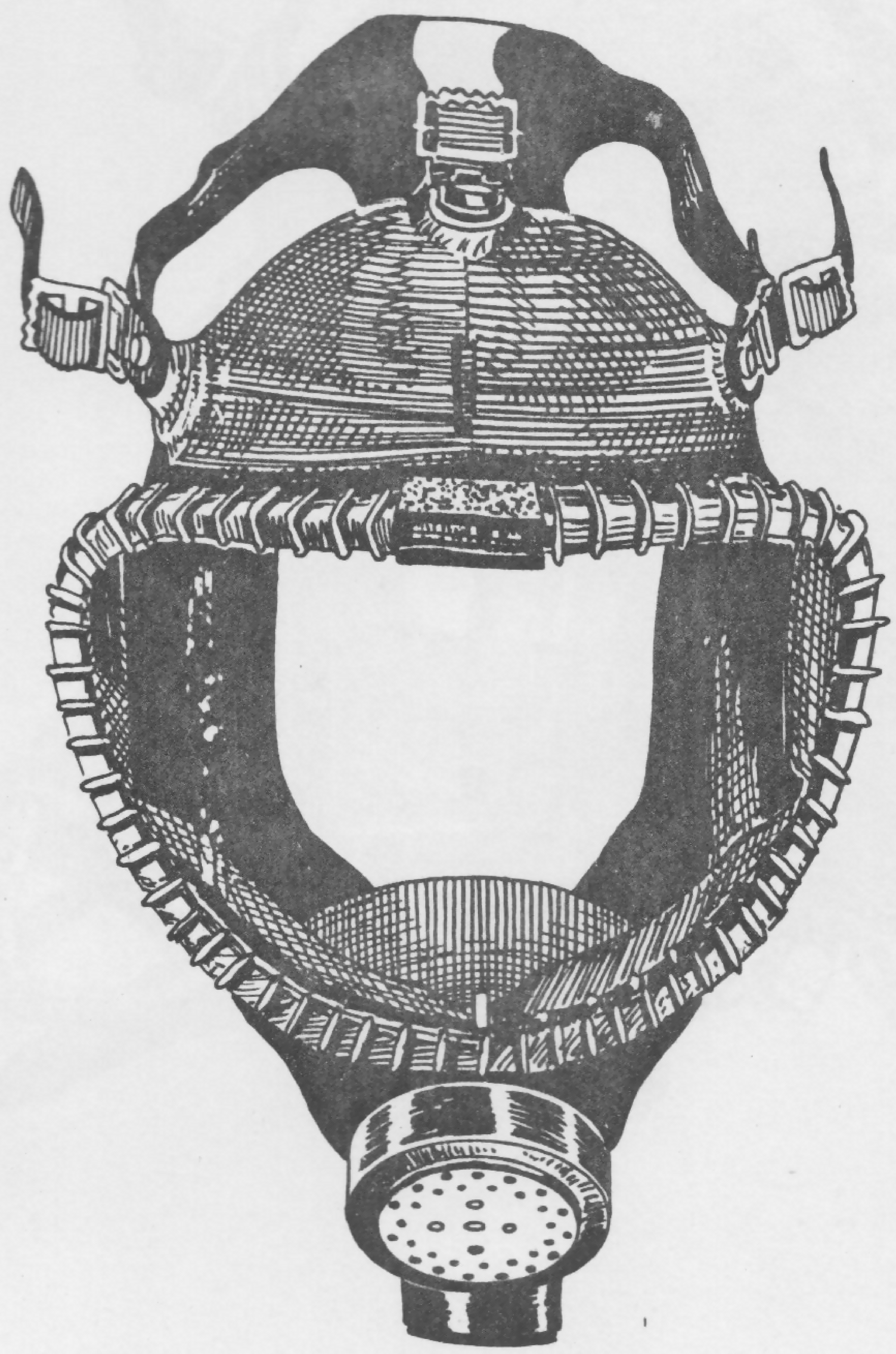
Caution: Respirators with mechanical filters provide no protection against gaseous activity or in oxygen-deficient atmospheres.

Description

I. Class I - Filter-Type Respirators

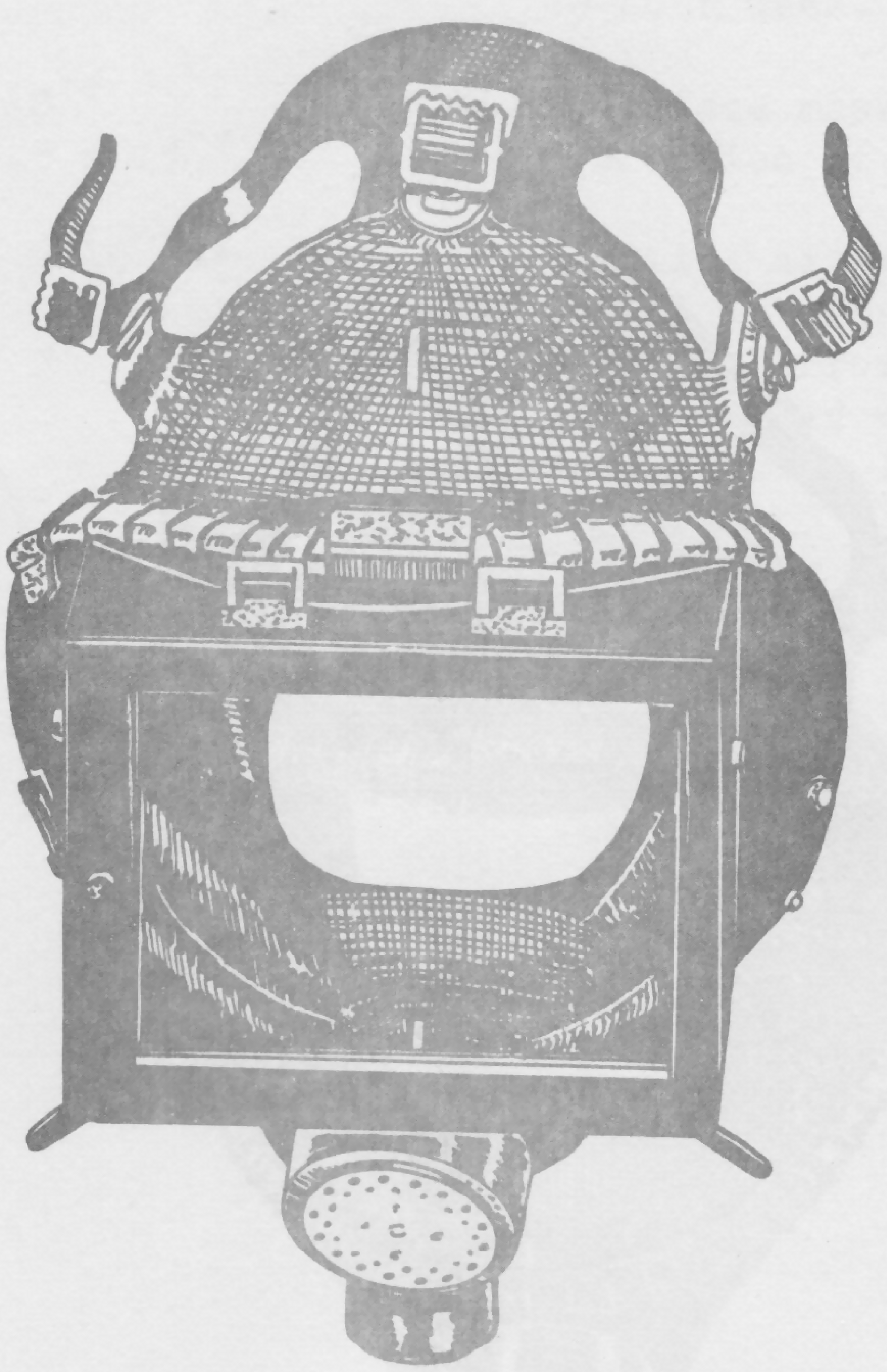
a. Full-Face Masks

The main limitations of the full-face mask are the possibility of leakage around the face and malfunctioning of the cartridge. It is possible to obtain less than 1 percent leakage for a properly fitted full-face mask. However, because of the difficulty of fitting all faces with a single size, it is generally assumed that full-face masks are 98-99 percent efficient.



Appendix III, Figure 1

FULL-FACE MASK



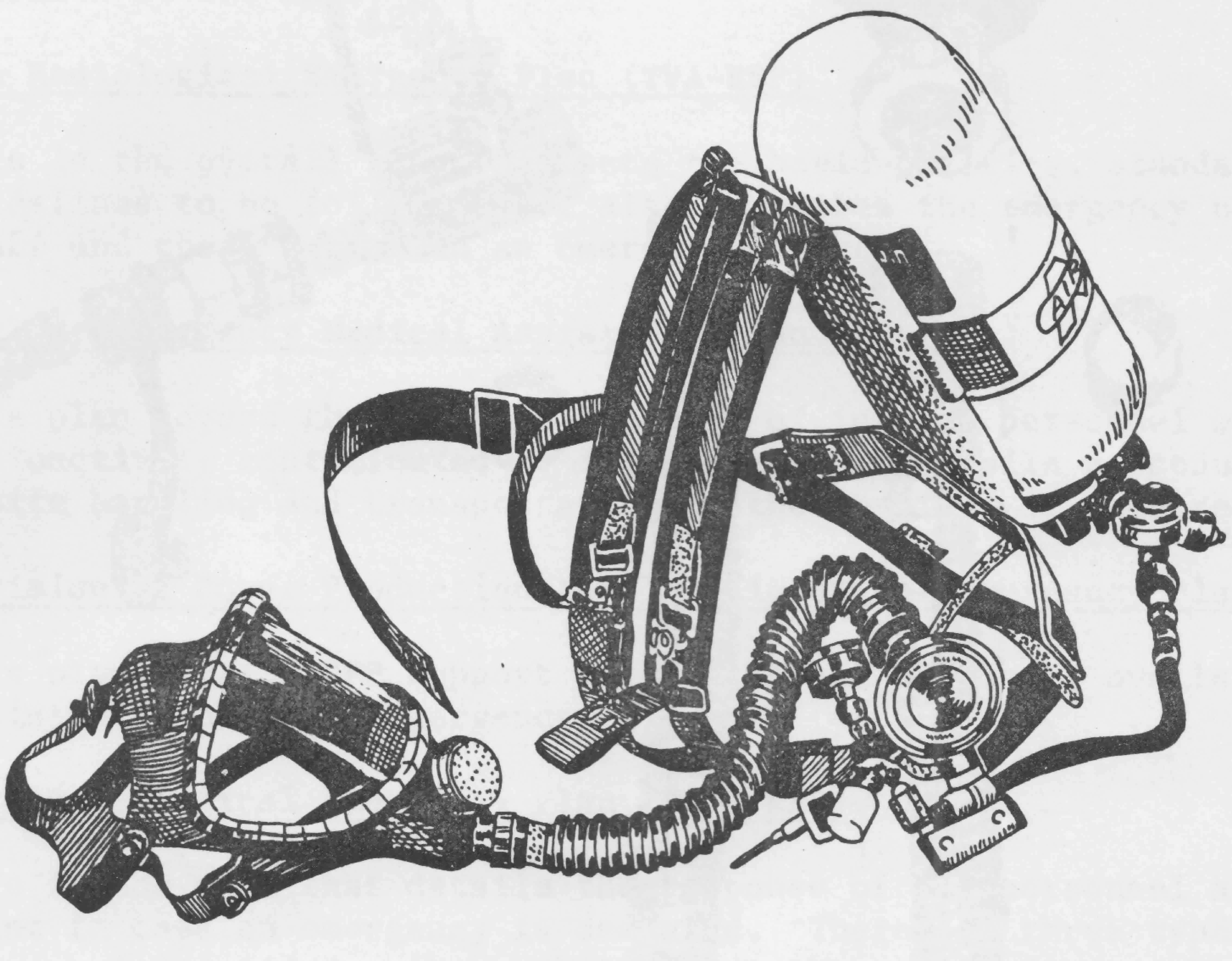
Appendix III, Figure 2

MSA WELDER'S MASK

2. Class II - Supplied-Air Masks

a. Pressure Demand Type

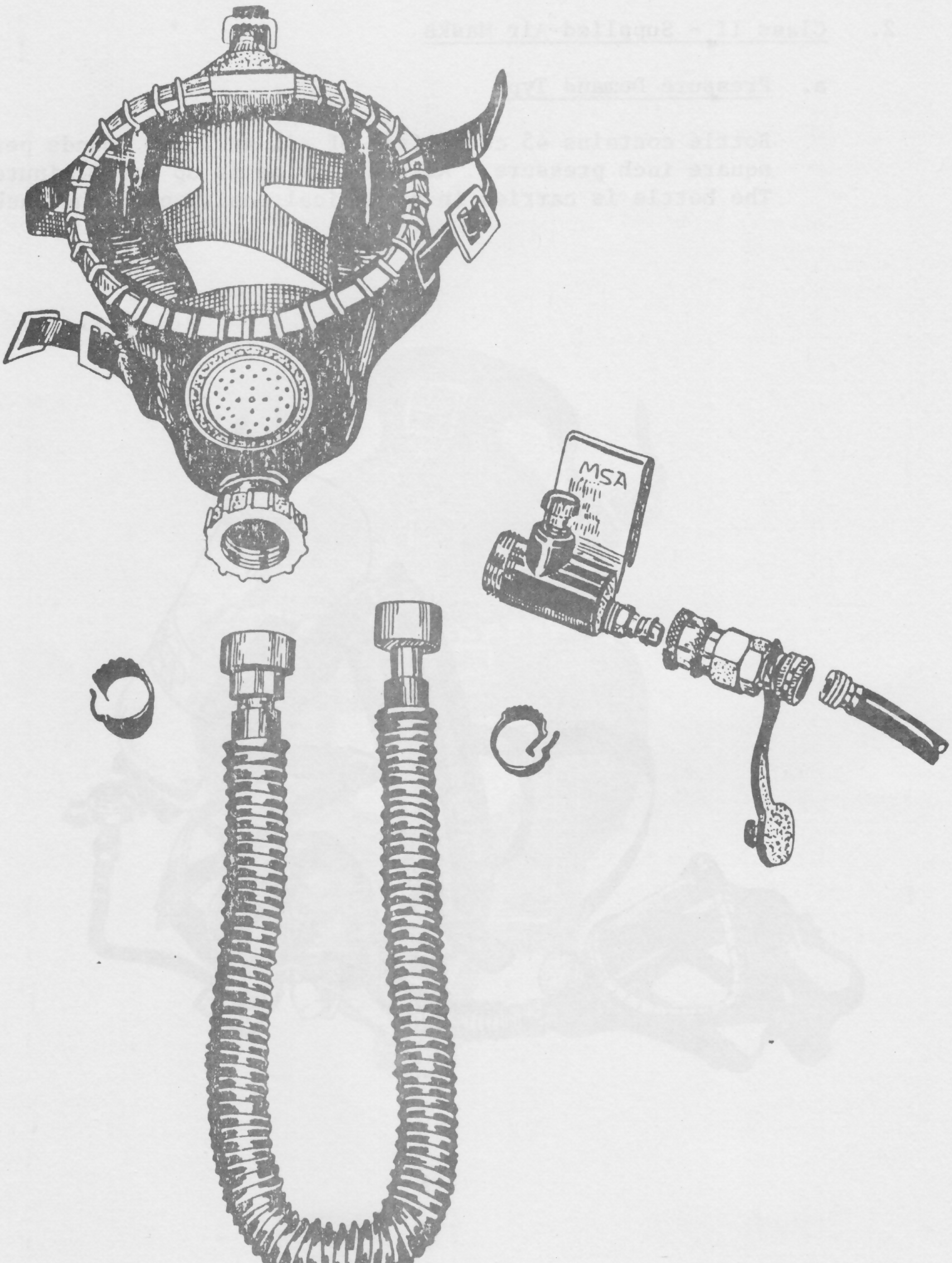
Bottle contains 45 cubic feet of air at 2,200 pounds per square inch pressure. Allowable time is up to 30 minutes. The bottle is carried in a vertical position on the back.



Appendix III, Figure 3

PRESSURE DEMAND TYPE

b. Air-Line Equipment



Appendix III, Figure 4

HOSE MASK WITH CONSTANT-FLOW REGULATOR

Appendix IV

RADIOLOGICAL EMERGENCY PLAN

The TVA Radiological Emergency Plan is a comprehensive document that sets forth policies, purposes, standards, guidelines, and, where feasible, specific instructions necessary for response to a radiological emergency within TVA. It has several sections, many of which apply to a particular plant. Since most sections of the overall plan affect only the emergency director and shift engineer, these sections will only be mentioned here. The site plan for the plant will be discussed in more detail as it affects all personnel at the site.

A. TVA Radiological Emergency Plan (TVA-REP)

This is the overall plan that sets the basic policies, standards, and guidelines to be followed. It also describes the emergency organization staff and their duties in an emergency.

B. Nuclear Emergency Medical Assistance Plan (MAP)

This plan covers the care and handling of injured personnel who are radioactively contaminated or irradiated. It details procedures for onsite handling and transportation to the hospital if required.

C. Division of Power Production (DPP) Radiological Emergency Plan

This plan details DPP support activities and personnel available to assist a plant in an emergency.

D. Site Radiological Emergency Plan (SITE-REP)

This is the plan that details the response of all personnel at the plant in case an emergency is declared. There are three types of emergencies defined: those that affect the public, those that affect plant personnel, and those that affect both plant personnel and the public.

The three conditions that could cause an emergency to be declared are abnormal gaseous radioactivity releases, liquid radioactivity releases, and radiation levels. Gaseous and liquid releases are those that may affect the public while abnormal radiation levels will normally be limited to plant personnel. It is probable that more than one condition could exist simultaneously.

The emergency organization consists of an emergency director (normally the plant superintendent or specified alternate or the shift engineer in their absence) and the following persons or their designated alternates: assistant superintendent, operations supervisor, plant results supervisor, mechanical and electrical maintenance supervisor, health physics supervisor, stores supervisor, PSO engineering unit supervisor, and public safety supervisor.

On the declaration of an emergency, the emergency organization assembles in the primary emergency control center. If the primary control center is untenable, the emergency organization assembles at the alternate assembly point. Each of these control centers has a stock of emergency supplies and additional emergency supplies are located in the gatehouse and in the meteorological tower building.

The activation of the emergency plan for plant personnel will be either by siren or public address system announcement. The siren will be used for total plant evacuation and the public address system will be used to clear only a particular area.

1. <u>Personnel Within Affected Area</u>

   If only a particular area is cleared, personnel in that area will evacuate to a safe area. The senior individual present will account for all personnel present and make a report to the emergency director. All supervisory personnel onsite will report the name of any individual(s) known to be within the evacuated area. The supervisors will then make an accounting of personnel assigned to them and report the results to the emergency director. In the case where only a particular area has been cleared, the following people will respond as follows:

   a. <u>All Persons Within Affected Area</u>

      Evacuate to a safe area. The senior individual present will account for all personnel present and report to the emergency director. Remain in assembly area for further instructions.

   b. <u>Emergency Control Organization</u>

      Report immediately to the emergency director in the emergency control center.

   c. <u>Health Physics Technician</u>

      Contact emergency control center to determine the nature of the incident and receive any instructions. Gather required equipment and stand by near affected area for further instructions.

2. <u>All Plant Employees and Escorted Visitors Not in Affected Area</u>

Report to your supervisor or the emergency control center, depending on individual circumstances, for accountability purposes. If not instructed otherwise, continue assigned tasks.

3. <u>Total Plant Evacuation</u>

Upon hearing the emergency siren, all persons in the plant go to their preassigned areas to await completion of radiological surveys and further instructions. Assembly areas are identified by painted signs. Directional arrows pointing to these areas are placed throughout the plant. Upon hearing the emergency siren, these people will respond as follows:

a. <u>Emergency Control Organization</u>

Report immediately to the emergency director in the emergency control center. If not onsite they will be notified by the shift engineer and report as quickly as possible.

b. <u>Operators</u>

If outside the control room, secure the operation in which they are engaged and proceed to the control room for further instructions and accountability. If within the control room, remain there for instructions and accountability. Each assistant shift engineer will account for operating personnel assigned to his unit and report to the shift engineer.

c. <u>Health Physics Technician</u>

Proceed to the health physics laboratory in the service bay and make an accountability report to the emergency director; stand by for instructions.

d. <u>All Other Plant Employees and Escorted Visitors</u>

Proceed to the assembly area for accountability and further instructions. The administrative officer or his assistant will serve as the accounting officer. During off shifts, the emergency director appoints and dispatches an accounting officer to the assembly areas.

(1) Each craft foreman will account for persons assigned to him and report results to the machine shop accounting officer.

(2) The property and supply officer will account for power stores employees and report results to the machine shop accounting officer.

(3) The communications engineer will account for all PSO engineering unit people and report results to the machine shop accounting officer.

(4) Visitors' escorts will account for their visitors and report results to the machine shop accounting officer.

(5) All other power annual employees report individually to the machine shop accounting officer.

(a) In the absence of the craft foreman or other designated group accountant, the machine shop accounting officer will appoint someone to perform this function.

(b) The machine shop accounting officer will provide the emergency director accountability information for all personnel assembled in the machine shop.

(c) If there are persons who cannot be accounted for, the emergency director will dispatch a search and rescue team.

4. Visitors Outside Plant Controlled Areas

Upon hearing the emergency siren, the public safety officer on duty at the gate will lock all gates to ensure controlled entrance and exit. Using the public safety radio communicating system, he will summon additional public safety officers via the TVA Public Safety Radio Network to assist in evacuation of all visitors from TVA land and adjacent water areas outside the fenced area. He will then assemble all nonescorted visitors in the assembly room of the office building and account to the emergency director. Visitors' names and addresses will be recorded and they will be escorted to the main gate, where health physics personnel will check all people and vehicles for contamination prior to release. Affected areas of the lake will be evacuated by the State Division of Water Safety as defined in that section of the State Plan. If only a particular area is cleared, the public safety officer will restrict entry of nonescorted visitors and request any who may be in the office area to leave.

5. Evacuation of the Plant Area

If he deems it necessary, or if radiation levels at the assembly point would cause a radiation exposure of 100 mrem or if airborne radioactivity is in excess of MPC, the emergency director, using the public address system, will order evacuation to the employee

parking lot. Employees will be released from this assembly point when the emergency director determines it is suitable. He will ensure that all people and vehicles pass through the health physics checkpoint adjacent to the main gate for survey prior to being released. If radiation levels at the employee parking lot are unsafe for occupancy, the assembly point will be moved to a safe place. Instructions will be given by the emergency director, based on local radiation and contamination conditions. He may recall evacuated people as needed.

6. Plant Re-entry

As soon as possible after personnel evacuation has been accomplished, procedures will be initiated to restore the plant to normal conditions. However, before any re-entry is attempted, complete radiation and contamination surveys will be made. The emergency director will authorize re-entry only when he is assured that the emergency has been controlled.

E. Environs Emergency Plan

This plan outlines the procedures and organization to monitor the environment in the emergency situation. The personnel involved are from the Muscle Shoals office of the Radiological Hygiene Branch. This plan is activated by notification of the Environs Emergency Staff by the TVA Duty Specialist.

F. State Radiation Emergency Plan

In the highly unlikely situation where evacuation of the public is required, the State authorities will perform this function. The State Department of Public Health is the responsible agency, but a number of other State agencies such as the Civil Defense Department, Department of Public Safety (Highway Patrol), Division of Water Safety, etc., have been given various functions that they can best perform. This plan details the procedures and functions of the various State agencies.

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Plant Recovery

As soon as possible after personnel evacuation has been accomplished, procedures will be initiated to restore the plant to normal conditions. However, before any re-entry is attempted, complete radiation and contamination surveys will be made. The emergency director will authorize re-entry only when he is assured that the emergency has been controlled.

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